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Environmental Monitoring Report for the Point Lepreau, N.B. Nuclear Generating Station - 1989, 1990

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ABSTRACT

Ellis, K.M., R.W.P. Nelson and J.N. Smith. 1992. Environmental monitoring report for the Point Lepreau, N.B., Nuclear Generating Station - 1989, 1990. Can. Tech. Rep. Hydrogr. Ocean Sci. No. 142: iv + 57 pp.

The Point Lepreau Environmental Monitoring Program (PLEMP) was established within the Department of Fisheries and Oceans in 1978 to assess the environmental impact of radioactive, thermal and chemical releases from the Point Lepreau N.B. Nuclear Generating Station (NGS) located on the Bay of Fundy. This report contains results from the seventh and eighth years of the operational phase of the program. A cost-effective reduction in the sampling program was facilitated by identifying indicator species at three primary locations at Point Lepreau N.B. and Digby, N.S. Samples were collected from the marine, atmospheric, terrestrial and freshwater environment in the vicinity of the Point Lepreau NGS for radionuclide analysis. Levels measured in these samples were compared to pre-operational levels to assess the environmental implications of the operation of nuclear reactors in coastal regions and to determine various parameters associated with the long term transport of radionuclides. Tritium remains the only radionuclide released from the Point Lepreau NGS which can be detected in vegetation, water and air, although levels are significantly below those considered harmful to organisms.

RÉSUMÉ

Ellis, K.M., R.W.P. Nelson and J.N. Smith. 1992. Environmental monitoring report for the Point Lepreau, N.B., Nuclear Generating Station - 1989, 1990. Can. Tech. Rep. Hydrogr. Ocean Sci. No. 142: iv + 57 pp.

Le Programme de surveillance de l'environnement de Point Lepreau a été mis en oeuvre par le ministère des Pêches et des Océans en 1978 afin d'évaluer l'impact des décharges radioactives, thermiques et chimiques de la centrale nucléaire de Point Lepreau, située en bordure de la baie de Fundy. Le présent rapport expose les résultats de la septième et de la huitième années d'application du programme. On est parvenu à une réduction rentable de l'échantillonnage en cernant des espèces indicatrices en trois endroits principaux à Point Lepreau (N.-B.) et Digby (N.-É.). On a comparé les résultats d'analyse d'échantillons de radionucléides prélevés en milieux marin, atmosphérique et terrestre ainsi qu'en eau douce aux environs de la centrale aux données recueillies dans la phase préopérationnelle du programme, dans le but d'établir les impacts environnementaux des réacteurs nucléaires sur les régions côtières et de définir divers paramètres relatifs au transport des radionucléides à long terme. Le tritium reste le seul radionucléide émanant de la centrale de Point Lepreau à avoir été décelé dans la végétation, dans l'eau et dans l'air, quoique ses concentrations soient bien inférieures à celles qui sont considérées nocives aux organismes.

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1.0 INTRODUCTION

The Point Lepreau Environmental Monitoring Program (PLEMP) was established in 1978 to assess the impact of the operation of the CANDU 600 MW nuclear reactor which was built at Point Lepreau on the shores of the Bay of Fundy (Figure 1). PLEMP, under the advisement of a working group made up of scientists from various departments (Appendix 1), was designed to provide a broad understanding of the processes which affect the radioactivity released from the Point Lepreau Nuclear Generating Station (NGS) into the surrounding environment. The sampling program includes the collection of samples from the major environmental reservoirs - atmospheric, marine, terrestrial and freshwater - on a regular basis and the measurement of key oceanographic variables in order to identify transport pathways and to determine fluxes of radionuclides along specific pathways.

The responsibility for PLEMP has been assigned to the Atlantic Environmental Radiation Unit (AERU) within the Marine Chemistry Division, Scotia-Fundy region, Department of Fisheries and Oceans, located at the Bedford Institute of Oceanography, Dartmouth, N.S.

PLEMP has been carried out in two phases. The pre-operational program ran from 1978 to 1982 when the reactor became operational. Results are summarized in Bishop *et al* (1980), Smith *et al* (1981, 1982) and Ellis *et al* (1984). Results for the second phase, i.e. the operational program, are found in Nelson *et al* (1985, 1986, and 1988) and Ellis *et al* (1990). The present report includes data for samples collected in 1989 and 1990. All published reports related to the PLEMP monitoring program are listed in Appendix 2.

The monitoring program carried out during 1989 and 1990 represents a small reduction in the overall sampling effort. The detailed data base established in previous years has allowed a reduction in the number of species and sample locations without reducing the overall effectiveness

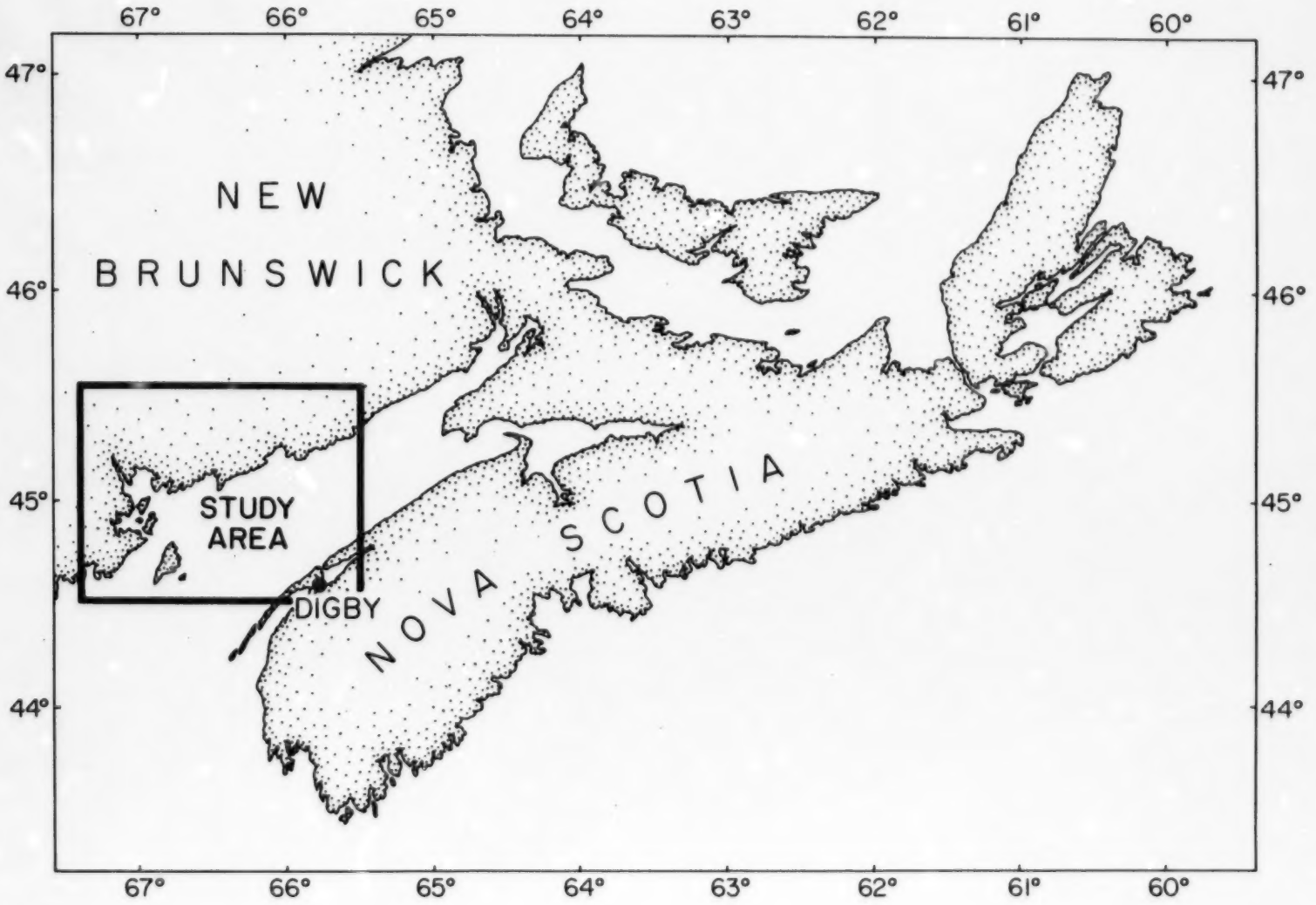

Figure 1: Location of the Point Lepreau Study Area on the Bay of Fundy.

of the program. The main reduction was in the number of air monitoring stations which was reduced by two, retaining a site close to the reactor, a second site 17 km north of the reactor at Musquash, N.B. and a third site at Digby in Nova Scotia. The temporal study of radionuclides in lichen and of tritium in conifer needles was also continued through 1989 and 1990.

In addition to monitoring releases from the Point Lepreau reactor, the monitoring program has been useful in studying atmospheric nuclear fallout, in particular inputs from the Chinese nuclear test in 1980 (Ellis and Smith, 1987) and from the Chernobyl nuclear power station accident in 1986 (Nelson *el al*, 1988, Smith and Ellis, 1990).

2.0 POINT LEPREAU GENERATION STATION EFFLUENT RELEASES

Radioactive materials are produced as a result of various processes involved in the production of nuclear power (e.g. activation products created by neutron activation of reactor support and encasement materials) and are released to the atmospheric, freshwater, terrestrial or marine environment from the Point Lepreau NGS. These emissions to the environment are monitored at the source under the mandate of the Liquid Effluent Monitoring Program (LEM) and the Gaseous Effluent Monitoring Program (GEM) conducted by the New Brunswick Electric Power Commission (NBEPC). During 1989 and 1990, the reactor operated at full power with the exception of brief outages and annual maintenance shutdowns for two to three weeks in April-May each year.

The liquid effluent monthly summaries are presented in Table 1 for 1989 (NBEPC, 1989) and in Table 2 for 1990 (NBEPC, 1990). Monthly summaries for previous years have been included in earlier reports (Appendix 2). The quantity of tritium released in 1989 and 1990 increased by a small amount compared to previous years. The total activity of all other isotopes continued to increase in 1989 and 1990, with the exception of I-131, Co-58, Ru-103, Ru-106 and Ag-110m. Tritium was the only radioisotope measured in weekly gaseous effluent releases, as illustrated in Figure 2. All releases are well below the DEL (Derived Emission Limits) set by Atomic Energy Control Board (AECB).

Table 1: Radionuclides in Liquid Effluent in 1989 (NBEPC, 1989).

Isotope	Monthly DEL (Bq)	Monthly Release (Bq)												Total (Bq)
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
H-3	4E18	4E12	4E12	3E12	2E13	4E13	4E12	4E12	4E12	1E13	2E14	8E12	8E12	3.2E14
C-14	1E14						1E8							1.1E8
Cr-51	2E15	1E6				2E6			4E6	2E7	6E6			3.8E7
Mn-54	2E13	2E5				4E5					1E7			1.6E7
Fe-59	1E13										9E6			8.6E6
Co-60	3E13	9E5				6E5		2E6	6E5	3E5	2E6	2E6	6E6	1.4E7
Zn-65	9E12								6E5	4E5	2E6	2E6	4E6	3.0E6
Sr-90	2E14				8E5	1E5	6E4							8.0E5
Nb-95	6E13	6E5	1E5	3E6	5E7	2E8	6E5	2E5	2E5	2E7	4E7	6E6	2E7	4.3E8
Zr-95	6E13	2E5		1E6	4E5	6E7	3E7	6E6	2E7	5E6	1E7	1E6	1E7	2.1E8
Ag-110m	1E13		3E5										2E5	5.6E5
Sb-124	1E12	3E5	5E7	2E6	2E5			3E6	4E6	4E6	3E6	3E6	6E6	9.3E7
I-131	1E13				2E7	5E6								3.3E7
Cs-134	4E13				2E5									2.5E5
Cs-137	7E13		5E6	2E5	4E6	7E5		4E5		1E5			1E6	1.1E7
Na-24	**		5E5											5.5E5
Sn-113	**					2E5								1.8E5
Sb-132	**								6E5	1E6				2.0E6
Te-132	**		4E6											3.6E6
Gd-153	**							2E6	1E6	2E6	5E7			5.4E7
Gd-159	**										1E6			1.3E6
Tb-160	**										1E7			1.1E7
W-187	**	6E5	1E6					7E5		3E6	2E6	1E6		9.0E6
Np-239	**										4E5			4.2E5

** No DEL calculated
No Ru-103, Ru-106, Ba-140, Ce-141, Ce-144 or Co-58 detected

Table 2: Radionuclides in Liquid Effluent in 1990 (NBEPC, 1990).

Isotope	Monthly DEL (Bq)	Monthly Release (Bq)												Total (Bq)
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
H-3	4E18	1E13	1E13	1E13	8E12	8E12	4E13	4E13	2E13	8E12	4E12	1E13	1E13	1.6E14
Cr-51	2E15			6E5			4E6					6E7	1E9	1.3E9
Mn-54	2E13			2E5			2E6	8E5				1E6		5.8E6
Fe-59	1E13						1E7					1E5		1.2E7
Co-60	3E13	2E6	1E6	9E6	2E7	9E5	3E7	1E7	1E6	2E6	9E5	2E6		8.8E7
Zn-65	9E12											8E5	5E6	5.5E6
Sr-90	2E14					2E5								2.2E5
Nb-95	6E13	6E6	1E7	6E6	4E6	4E6	3E7	3E6	5E6	2E6	5E5	4E6	5E5	1.1E8
Zr-95	6E13	1E6	6E6	3E6	2E7	2E5	1E7	3E5	1E6	3E5	2E5	1E6	2E5	5.3E7
Ru-103	1E14											7E5	3E5	1.2E6
Ag-110m	1E13		3E5			1E5	2E6					9E5		3.7E6
Sb-124	1E12	5E6	5E6	2E6	1E6	2E5	2E7	2E5	5E5	1E5	3E5	2E7	3E8	4.2E8
I-131	1E13			1E5	2E5		3E5							6.6E5
Cs-134	4E13	2E5						1E5						3.2E5
Cs-137	7E13	3E6	3E6	7E4	4E5	3E6	3E6							1.1E7
Ce-141	2E14		2E5									6E4		3.2E5
Na-24	**											3E6	9E7	9.1E7
Tc-99m	**	3E7												3.3E7
Mo-99	**					8E5						5E4	1E5	1.0E7
Sb-122	**	6E5			5E6			4E5	1E6	9E5		9E7	9E9	2.2E9
Te-132	**			3E5								2E5		5.2E5
I-133	**			3E5										2.8E5
Gd-153	**						2E7				3E7	2E7		3.8E7
Gd-159	**			2E6										1.8E6
Tb-160	**											6E6		6.4E6
W-187	**				1E8									1.2E8
Np-239	**			7E5										7.1E5

** No DEL calculated
No Ru-103, Ru-106, Ba-140, Ce-141, Ce-144 or Co-58 detected

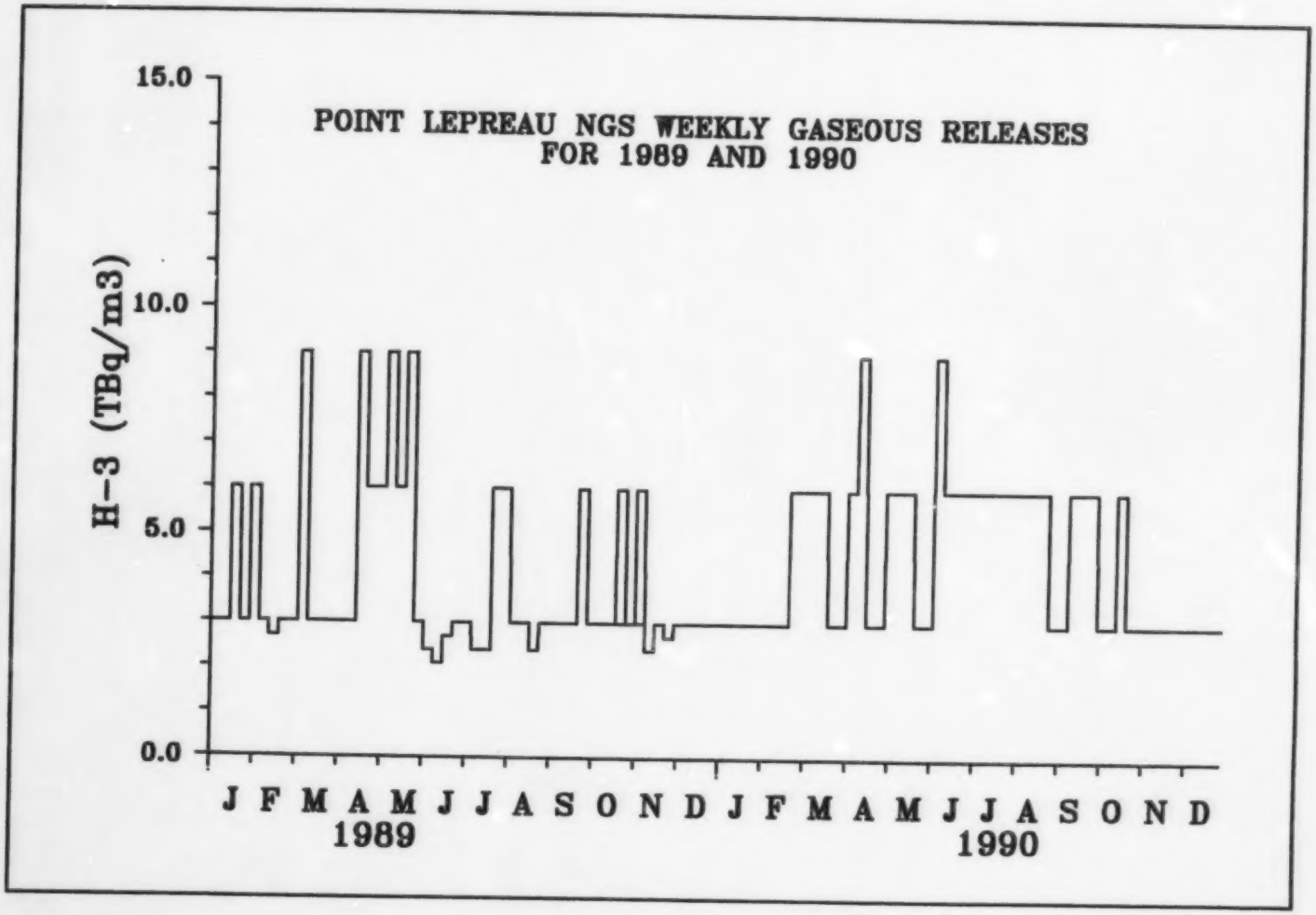

Figure 2: Point Lepreau NGS Weekly Gaseous Tritium Releases for 1989 and 1990.

3.0 MARINE ENVIRONMENT

3.1 WATER CIRCULATION

The largest tides of the world occur in the Bay of Fundy and influence the currents around Point Lepreau on a predominantly semi-diurnal basis. The extremely high tidal range (up to 16 m at the head of the Bay and 7 m at Point Lepreau) leads to a large volume of water entering and leaving the Bay and a fast flushing time, estimated at about 75 days for the Bay of Fundy (Ketchum and Keen, 1967).

Residual water circulation patterns in the Bay of Fundy are dominated by a cyclonic, anticlockwise gyre with inflow along the coast of Nova Scotia and outflow along the New Brunswick coast passing to the east of Grand Manan Island (Bumpus and Lauzier, 1965). Low salinity water created largely by inputs from the Saint John River (which accounts for up to 60 % of the freshwater inputs) flows out at the surface, while denser shelf and slope waters mix across the shelf break and enter the Bay of Fundy at depths predominately below 100 meters. Water circulation patterns are seasonal and are largely controlled by the amount of freshwater input. Maximum river runoff occurs in the spring, resulting in maximum stratification and reduced vertical mixing. During the other seasons when freshwater runoff is diminished, there is less stratification allowing more vertical mixing.

3.2 CHEMICAL OCEANOGRAPHY

3.2.1 Sampling

A seawater sample was collected from the shore at Duck Cove, east of Point Lepreau in the vicinity of the reactor effluent release, during the summer of 1989 and 1990. Large volume water samples (48 l) were collected and processed as illustrated in Figure 3. Water samples were passed

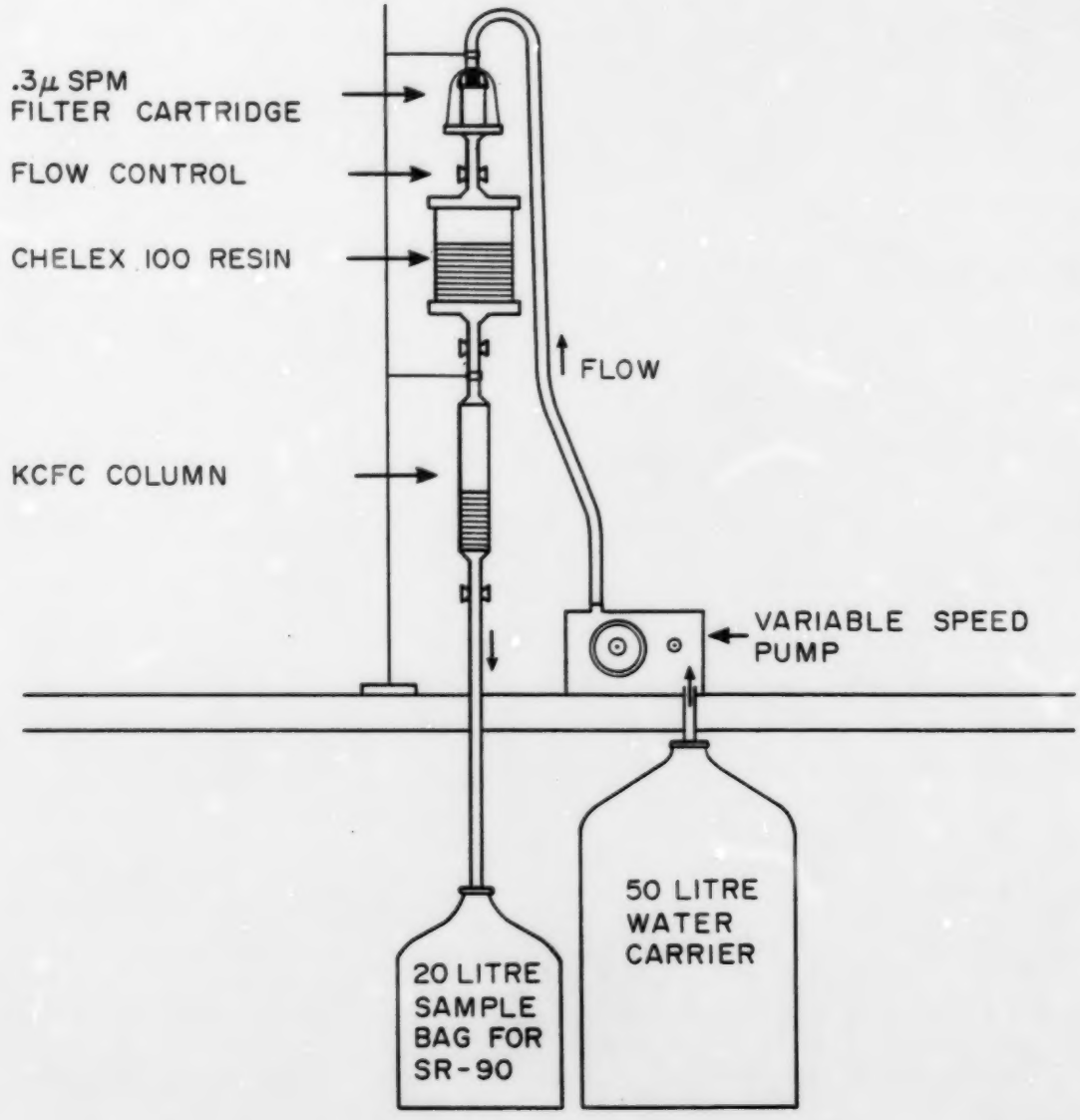

Figure 3: Schematic Diagram of Columns Used to Concentrate Radionuclides from Seawater.

through (1) a Whatman in-line cartridge filter to remove particles of size approximately 0.3 micrometers or larger; and (2) a KCFC column (potassium cobalt ferrocynide) to remove cesium (Cs-134 and Cs-137). An intertidal surface sediment sample was collected each year at Site I-17 in Duck Cove.

3.2.2 Water Results

Cesium-137 is a relatively long-lived ($t_{½}$ = 30.2 y) fission product which originates from nuclear weapons tests and nuclear power production. It is present is seawater in dissolved ionic form (Kupferman *et al*, 1979) and fallout Cs-137 is measurable in surface seawater. Results for Cs-137 for 1989 and 1990 are included in Table 3, which summarizes all values of Cs-137, Sr-90 and tritium measured during the pre-operational and operational phases of the monitoring program. Levels of Cs-137 measured in the 1989 and 1990 samples are within the range of levels measured in pre-operational samples.

Levels of Cs-137 and other gamma-emitting isotopes measured in suspended particulate matter samples were below detection limits. Detection limits for typical counting conditions (water volume of 48 l, counting time of 1500 minutes, one month after sample collection) are given in Table 4.

3.2.3 Sediment Results

Radionuclide results for intertidal sediments are given in Table 5. The low levels found for Cs-137 are typical of pre-operational levels in the Duck Cove area (Smith *et al*, 1982) The sediments to the east of Point Lepreau at Duck Cove are characterized as 'very sandy mud' (Loring, 1979) indicating sediments of larger particle size and smaller overall surface area, which typically have lower radionuclide concentrations.

Table 3: Average Radionuclide Values Measured in the Bay of Fundy Waters during the Monitoring Program.

Cruise No.	Sample Date	Radionuclide Concentration (mBq/l)*			
		Cs-137		Sr-90 Soluble	H-3 Total
		Part.	Soluble***		
Pre-operational					
79-007	May 1979	-	3.8 ± 0.7 (n=28)	3 ± 1	2700 ± 3000
79-027	Oct 1979	< 0.8	2.6 ± 0.8 (n=43)	-	1700 ± 2700
80-018	Jun 1980	< 0.8	4.2 ± 0.3 (n=43)	-	< 2300
81-500	Feb 1981	< 1.5	4.4 ± 0.5 (n=20)	-	2840 ± 120
81-050	Apr 1981	< 1.2	3.5 ± 0.3 (n=33)	-	2210 ± 580
Operational					
83-003	Apr 1983	-	3.3 ± 0.6 (n=30)	-	2525 ± 910
84-025	Jul 1984	< 0.4	3.0 ± 0.5 (n=28)	-	2933 ± 611
85-041	Dec 1985	< 0.5	3.2 ± 0.4 (n=18)	-	3885 ± 1343
87-015	May 1987	< 0.5	3.5 ± 0.3 (n=46)	3.6 ± 0.3 (n = 3)	< 3900
-	July 1989	< 2	3 ± 1**	-	-
-	June 1990	< 1	5 ± 1**	-	-

* Reported error is the standard deviation for the mean value
** Reported error is counting error
*** Mean radionuclide activities are calculated using a single value for the 24 hour anchor station.

Table 4: Detection limits for SPM in seawater for typical sampling and counting conditions (48 *l* sample, 1500 minute count time and 1 month between sample and counting times).

Nuclide	SPM	
	(Bq/g)	(mBq/*l*)
Co-56	1.0	1.5
Co-57	0.3	0.4
Co-58	1.1	1.6
Co-60	0.6	0.9
Cr-51	16	24
Fe-59	3.1	4.6
Mn-54	0.7	1.1
Zn-65	1.7	2.6
Cs-134	0.6	0.9
Cs-137	0.4	0.6

Table 5: Radionuclide Results for Intertidal Sediments Collected in 1989 and 1990.

Collection Date	Sample No.	Site No.	Cs-137 (Bq/kg)	Be-7 (Bq/kg)
26/07/89	35774	I-17	1.7 ± 0.2	< 200
13/06/90	35850	I-17	0.6 ± 0.1	< 134

4.0 ATMOSPHERIC MONITORING

The two principal components of the atmospheric monitoring program are: (1) the ongoing compilation of a meterological data base for the Point Lepreau region which can be applied to the transport of airborne pollutants under diverse weather conditions and utilized in atmospheric transport models, and (2) the collection of atmospheric samples (water vapour, gaseous I-131 and particulates) for radionuclide analysis.

4.1 Meteorological Data Collection

The meteorological data collection station is located in Musquash (Station 1, Figure 4) at the New Brunswick Department of Transport depot. The station consists of a Fischer and Porter precipitation gauge and a Campbell Scientific temperature and relative humidity probe. Wind speed and direction data (at elevation of 10 m) from an on-site tower at the Point Lepreau NGS was provided by NBEPC. The Atmospheric Environment Service extracts the wind, temperature, rainfall and relative humidity data for use in the monitoring program.

The monthly rainfall amounts, average monthly temperatures and average monthly wind speeds at Musquash are given in Table 6. The average annual rainfall of 1256 mm (σ = 186 mm) was measured for Musquash from 1981 to 1988 and indicates that typical amounts of rainfall fell in 1989 (1144 mm) while higher than normal amounts were recorded for 1990 (1624 mm). Monthly wind distributions are illustrated in Figure 5. The area is characterized by relatively high winds, of the order of 14 km/hr for a yearly average, with highest wind speeds occurring during the winter. Winter season is characterized by strong northly winds while summer winds have a dominant southwest component.

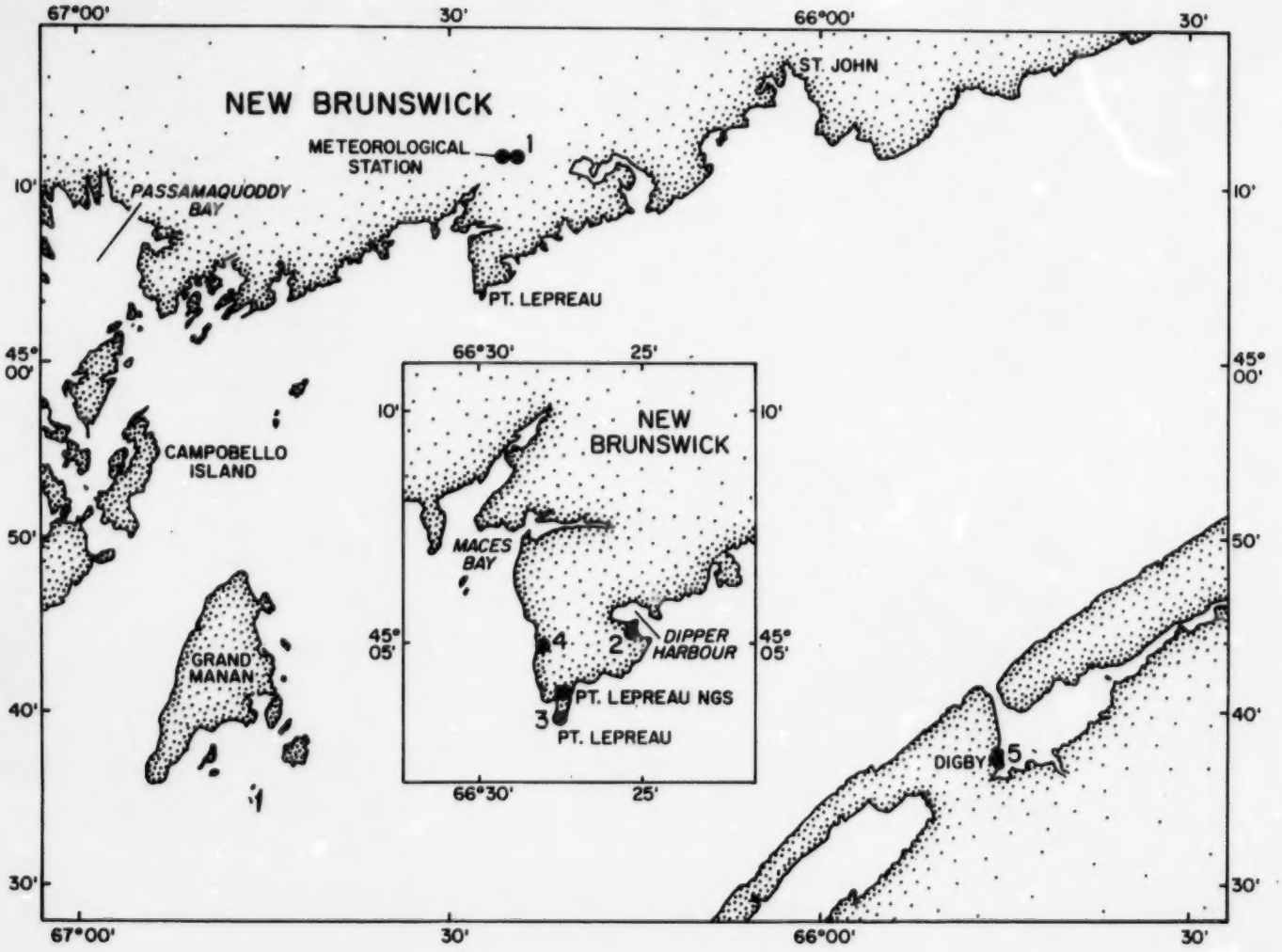

Figure 4: Station Locations of Air Monitoring Stations.

Table 6: Meteorological Data for Point Lepreau for 1989 and 1990.

Year - Month	Musquash Precipitation (mm)	Average Temperature (°C)	Average Wind Speed (km/h)
1989 - Jan	102.3	-5.6	18.7
Feb	75.1	-7.7	16.6
Mar	63.4	-3.2	16.6
Apr	91.5	2.9	16.5
May	188.8	11.3	9.5
Jun	92.0	14.9	10.3
Jul	82.6	17.8	8.9
Aug	82.1	16.2	8.5
Sept	87.6	13.2	12.1
Oct	87.4	8.7	14.9
Nov	198.1	2.4	18.6
Dec	84.6	-10.1	17.5
Total	1144.0		
1990 - Jan	164.8	-2.1	17.8
Feb	105.4	-5.5	16.6
Mar	56.7	-0.9	16.6
Apr	122.1	4.0	14.8
May	221.2	8.0	14.7
Jun	43.8	13.8	10.6
Jul	171.6	18.3	9.6
Aug	76.4	18.3	7.7
Sept	130.6	13.0	12.1
Oct	166.8	9.5	16.0
Nov	128.4	2.9	18.1
Dec	236.7	-0.9	18.7
Total	1624.5		

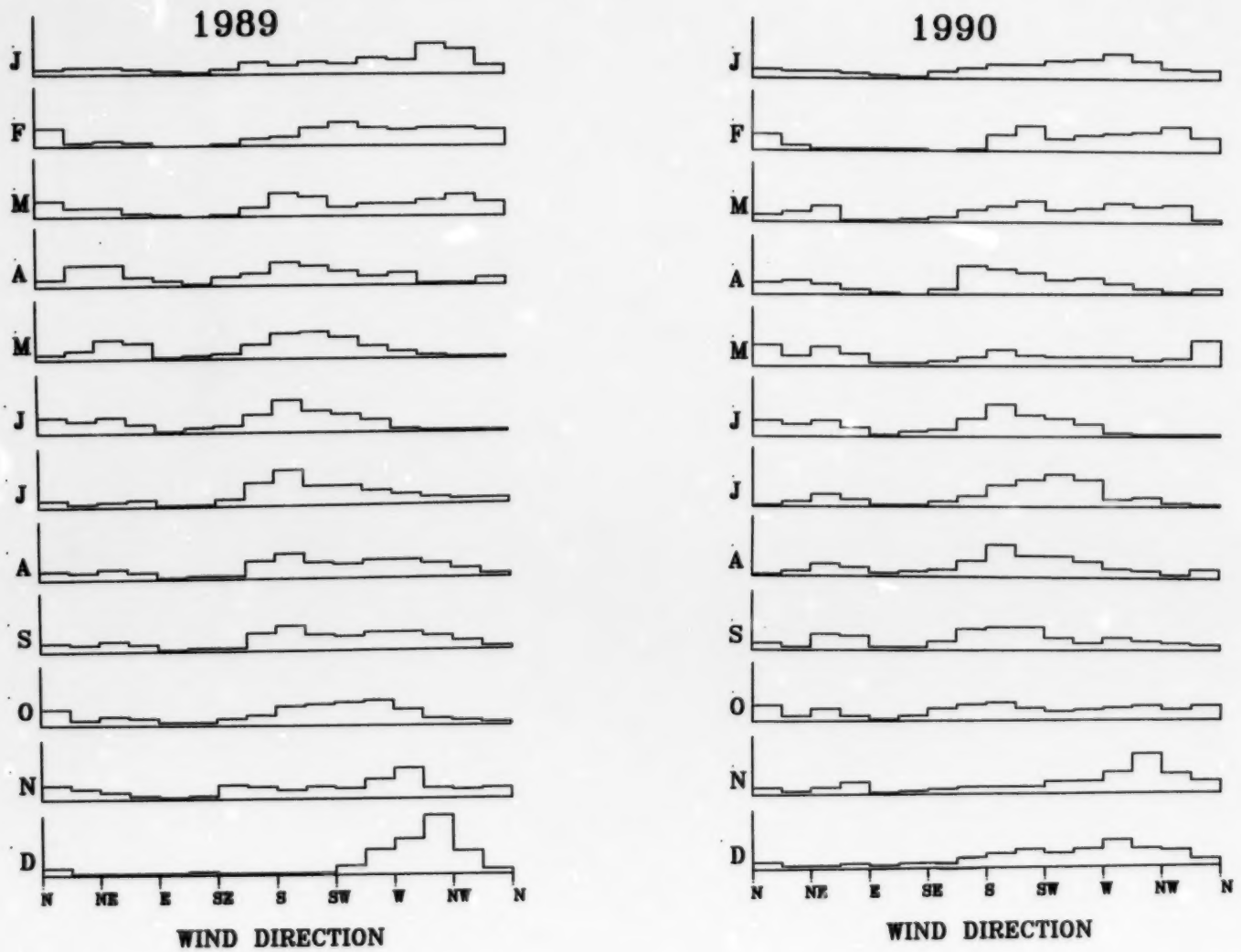

Figure 5: Monthly Wind Direction Distribution at Point Lepreau NGS for 1989 and 1990, Showing the Percentage of the Time during the Month (X-axis) for each of the 16 Wind Directions

4.2 Air Monitoring Results

AERU originally operated a network of five air monitoring stations at locations shown in Figure 4. As a result of reductions in the air monitoring program in 1989, two of the stations, Station 2, located at Dipper Harbour and Station 4, at Welch's Cove, were removed. The air monitoring station at Welch's Cove has been removed permanently but the station at Dipper Harbour was reinstalled in 1991. The design for the air monitoring stations is illustrated in Figure 6. The components have been described previously (Bishop *et al*, 1980, Ellis *et al*, 1990).

The approximate detection limits are $4x10^{-5}$ mBq/m^3 for particulate Cs-137, $3x10^{-2}$ mBq/m^3 for I-131 on the charcoal cartridge and $1x10^{-2}$ Bq/m^3 for H-3 in water vapour. These detection limits were determined assuming a 10 day delay between sampling and analysis.

4.2.1 Tritium

The tritium distributions in atmospheric moisture (Bq/l) for Stations 1 (Musquash), 3 (Point Lepreau) and 5 (Digby, N.S.) during 1989 and 1990 are illustrated in Figure 7. These values are converted to activities per air volume (Bq/m^3) using flow meter volumes for the molecular sieve or by using relative humidity and temperature data from the meteorological station at Musquash. Results for tritium (Bq/m^3) for 1989 and 1990 are given in Tables 7 and 8 and the distributions for 1989 and 1990 are illustrated in Figure 8 (Stations 1 and 5) and Figure 9 (Station 5).

Tritium activities in atmospheric moisture during the pre-operational phase (Smith *et al*, 1982) ranged from < 2 to 16 Bq/l with a mean tritium activity of 5.9 Bq/l. Activities higher than these background levels were measured at Station 1, located 17 km from the Point Lepreau NGS (which was originally classified as the control station), during the spring and summer when the humidity (i.e. the amount of moisture per liter of air) increases and the location was downwind of the prevalent southwest wind direction (Figure 5). Tritium activities in atmospheric moisture are

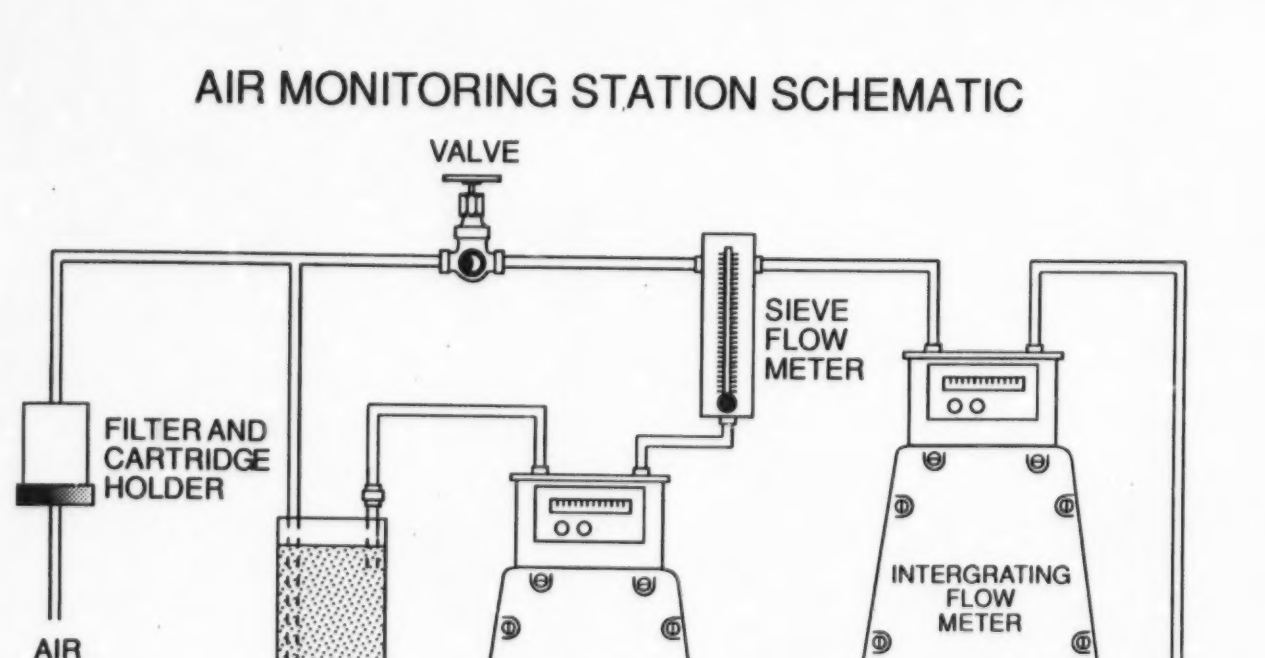

Figure 6: Schematic of an Air Monitoring Station.

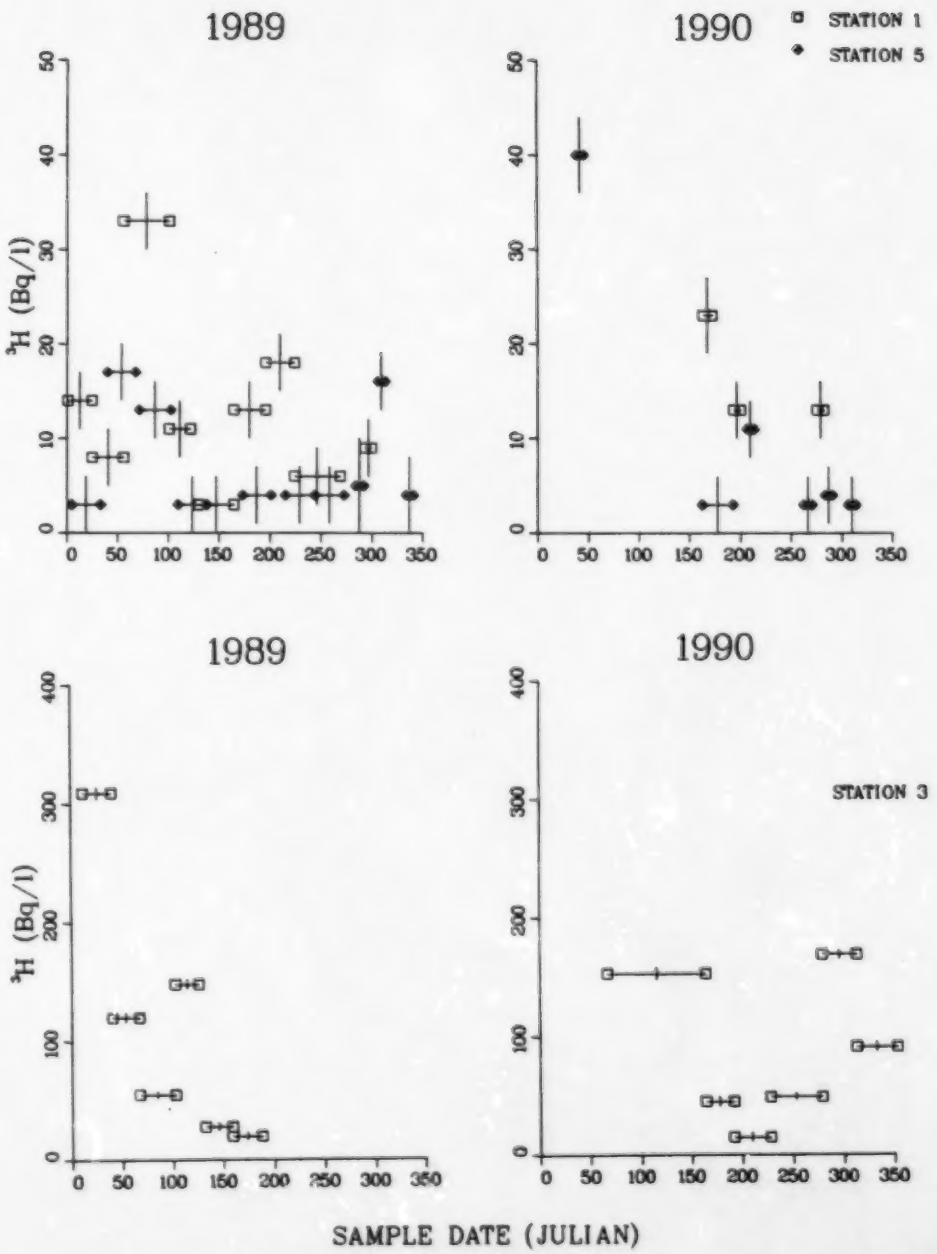

Figure 7: Tritium Activities Measured in Atmospheric Moisture (Bq/l) during 1989 and 1990 at Stations 1 (Musquash), 3 (Point Lepreau) and 5 (Digby, N.S.)

Table 7: Radionuclide Levels in Air in 1989.

Stn No	Sample No	Collection Date	Volume (m^3)	H-3 (Bq/m^3)	Be-7 (mBq/m^3)
1	35599	08/01	4471	0.020 ± 0.004	0.27 ± 0.05
	35604	09/02	4029	0.018 ± 0.006	0.08 ± 0.01
	35609	19/03	5703	0.079 ± 0.007	0.14 ± 0.02
	35615	21/04	2404	0.056 ± 0.015	0.25 ± 0.04
	35625	26/05	3012	0.045 ± 0.012	0.10 ± 0.04
	35628	28/06	2435	0.068 ± 0.015	0.44 ± 0.12
	35631	28/07	2487	0.153 ± 0.024	0.09 ± 0.03
	35634	03/09	3771	0.034 ± 0.018	-
	35646	23/10	662	0.057 ± 0.021	-
2	35600	04/01	4864	0.178 ± 0.009	1.03 ± 0.04
	35605	03/02	4216	0.042 ± 0.004	0.74 ± 0.04
	35610	16/03	7688	0.084 ± 0.005	1.09 ± 0.04
3	35601	25/01	4131	0.761 ± 0.012	1.95 ± 0.05
	35606	22/02	4066	0.255 ± 0.009	1.84 ± 0.03
	35611	25/03	5368	0.188 ± 0.010	0.94 ± 0.06
	35617	24/04	4142	0.698 ± 0.019	1.57 ± 0.02
	35626	25/05	4012	0.243 ± 0.026	1.14 ± 0.04
	35629	22/06	4153	0.193 ± 0.029	< 0.11
	35632	06/08	9166	0.108 ± 0.033	0.77 ± 0.02
	35635	19/09	4074	0.228 ± 0.035	1.60 ± 0.06
	35644	21/10	5969	0.729 ± 0.026	0.93 ± 0.03
5	35603	18/01	4556	0.004 ± 0.003	0.27 ± 0.02
	35608	22/02	1645	0.122 ± 0.020	1.75 ± 0.10
	35613	27/03	1862	0.017 ± 0.004	1.97 ± 0.09
	35619	03/05	2632	0.005 ± 0.004	0.44 ± 0.07
	35627	05/07	1366	0.009 ± 0.006	< 0.27
	35630	16/08	1662	0.004 ± 0.003	0.69 ± 0.07
	35633	14/09	1661	0.005 ± 0.005	1.49 ± 0.09
	35645	10/10	408	< 0.013	1.96 ± 0.27
	35648	05/11	412	0.044 ± 0.009	1.22 ± 0.17
	35651	03/12	456	< 0.012	-

Table 8: Radionuclide Levels in Air in 1990.

Stn No	Sample No	Collection Date	Volume (m^3)	H-3 (Bq/m^3)	Be-7 (mBq/m^3)
1	35657	17/06	629	0.074 ± 0.012	0.69 ± 0.19
	35661	15/07	507	0.120 ± 0.034	2.26 ± 0.13
	35664	06/10	200	0.044 ± 0.009	2.90 ± 0.40
3	35650	25/01	7597	-	1.37 ± 0.02
	35653	25/04	8628	0.829 ± 0.027	1.74 ± 0.09
	35656	26/06	1521	0.489 ± 0.043	0.55 ± 0.06
	35659	28/07	3876	0.187 ± 0.050	< 0.2
	35662	09/09	5595	0.445 ± 0.028	1.25 ± 0.01
	35665	22/10	4965	1.102 ± 0.026	0.28 ± 0.01
	35668	28/11	4578	0.368 ± 0.012	1.19 ± 0.03
5	35654	11/02	419	0.143 ± 0.013	2.42 ± 0.31
	35655	26/06	1606	0.013 ± 0.012	1.48 ± 0.08
	35663	29/07	343	0.102 ± 0.033	1.04 ± 0.01
	35666	23/09	465	0.012 ± 0.011	0.78 ± 0.13
	35669	13/10	440	0.030 ± 0.020	5.00 ± 1.00
	35672	04/11	1779	0.004 ± 0.004	0.36 ± 0.07

highest at the closest air monitoring site, Station 3, at the tip of Point Lepreau. Activities range from 10 to 300 Bq/l with mean values of approximately 100 Bq/l for 1989 and 1990 and with maximum values generally measured in the winter and spring, when the wind field is dominated by north-northeast winds, the direction required to carry the plume over Station 3. Tritium activities measured at Digby N.S. (Station 5) in 1989 and 1990 (range of 2 to 17 Bq/l and an average of 5 Bq/l) are similar to pre-operational values.

Pre-operational tritium levels (Bq/m^3) ranged from < 0.01 to 0.2 Bq/m^3 with an average value of 0.07 Bq/m^3 and higher values in the summer when humidity levels are higher. Higher activities,

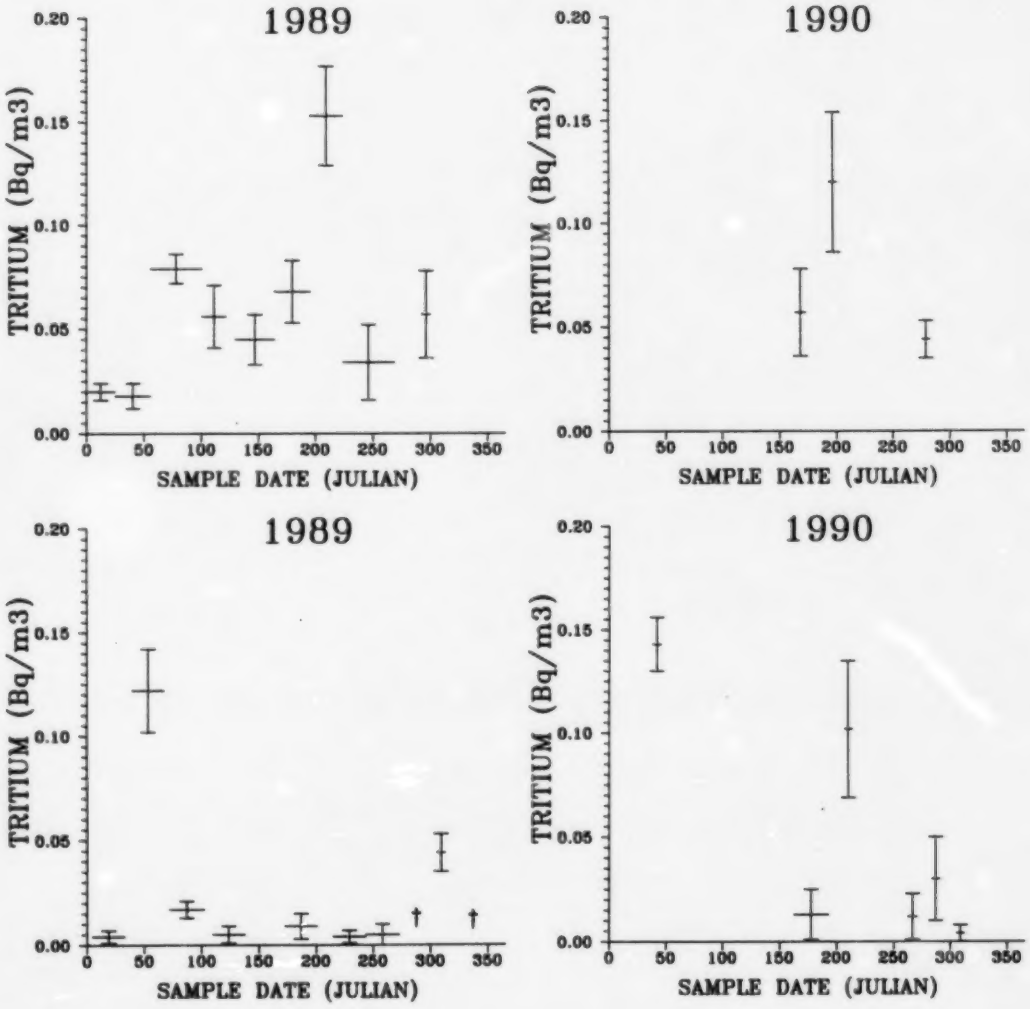

Figure 8: Tritium Activities Measured in Air (Bq/m³) during 1989 and 1990 at the Station 1 at Musquash, (top) and 5 at Digby, N.S. (bottom). † represents a 'less than' value.

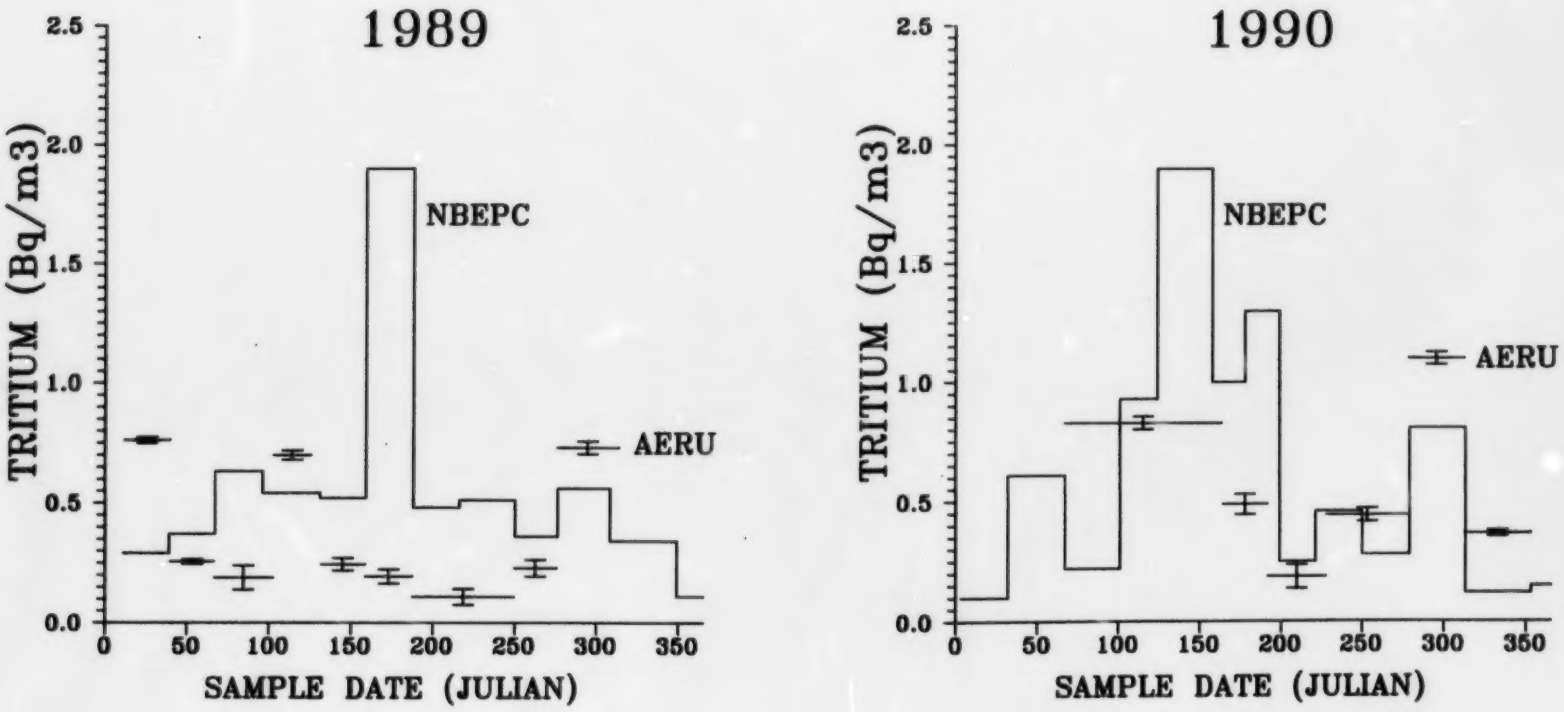

Figure 9: Tritium Activities Measured in Air (Bq/m³) during 1989 and 1990 at the Tip of Point Lepreau Peninsula (AERU, Station 3). Measurements made by the New Brunswick Electric Power Corporation (NBEPC) for the same location and time period are included for comparison.

ranging from 0.11 to 1.102 Bq/m^3, were measured in 1989 and 1990 at Station 3, near the Point Lepreau NGS. Tritium levels measured during the same time by NBEPC (1987, 1988) at Station 3 are also shown in Figure 9 and are in reasonable agreement with the AERU values. The history of tritium activities in air (Bq/m^3) since the beginning of the monitoring program (Figure 10) illustrates the increase in the tritium activity with time, particularly at Station 3 and a small increase observed at Station 1.

4.2.2 Air Filters and Cartridges

Air filters, which collect the airborne particulate matter and air cartridges, which collect gaseous radionuclides, were analyzed for gamma-emitting radionuclides by direct counting on hyper-pure Ge detectors. No isotopes, including I-131, were measured on the charcoal cartridge and only Be-7, a naturally occurring radioisotope, was detected on the filters. The results are presented in Table 7 for 1989, Table 8 for 1990 and in Figure 11. Because of its high specific activity, its short half-life (53 days) and its particle affinity, Be-7 is useful in estimating aerosol residence times in the upper troposphere and particle deposition rates (Olsen *et al* 1985, Graustein and Turekian 1986).

The Be-7 activities have a range of 0.08 to 1.97 mBq/m^3 and an average value of 0.90 mBq/m^3 for all stations in 1989 and a range of 0.36 to 5.00 mBq/m^3 with an average value of 1.88 mBq/m^3 in 1990. The activities measured in 1989 are unusually low for Stations 1 and 5 and appear to be a result of problems encountered in measuring sample volumes. These problems were corrected by 1990 and activities measured in 1990 are in the range of activities measured in previous years. Beryllium-7 activity increases in the spring at all stations when levels in the troposphere are augmented by inputs from the stratosphere (where it is produced) during the annual mixing of the stratosphere and the troposphere (Olsen *et al*, 1985). Differences between stations, normalized to individual precipitation rates, give an indication of the variance in local deposition rates.

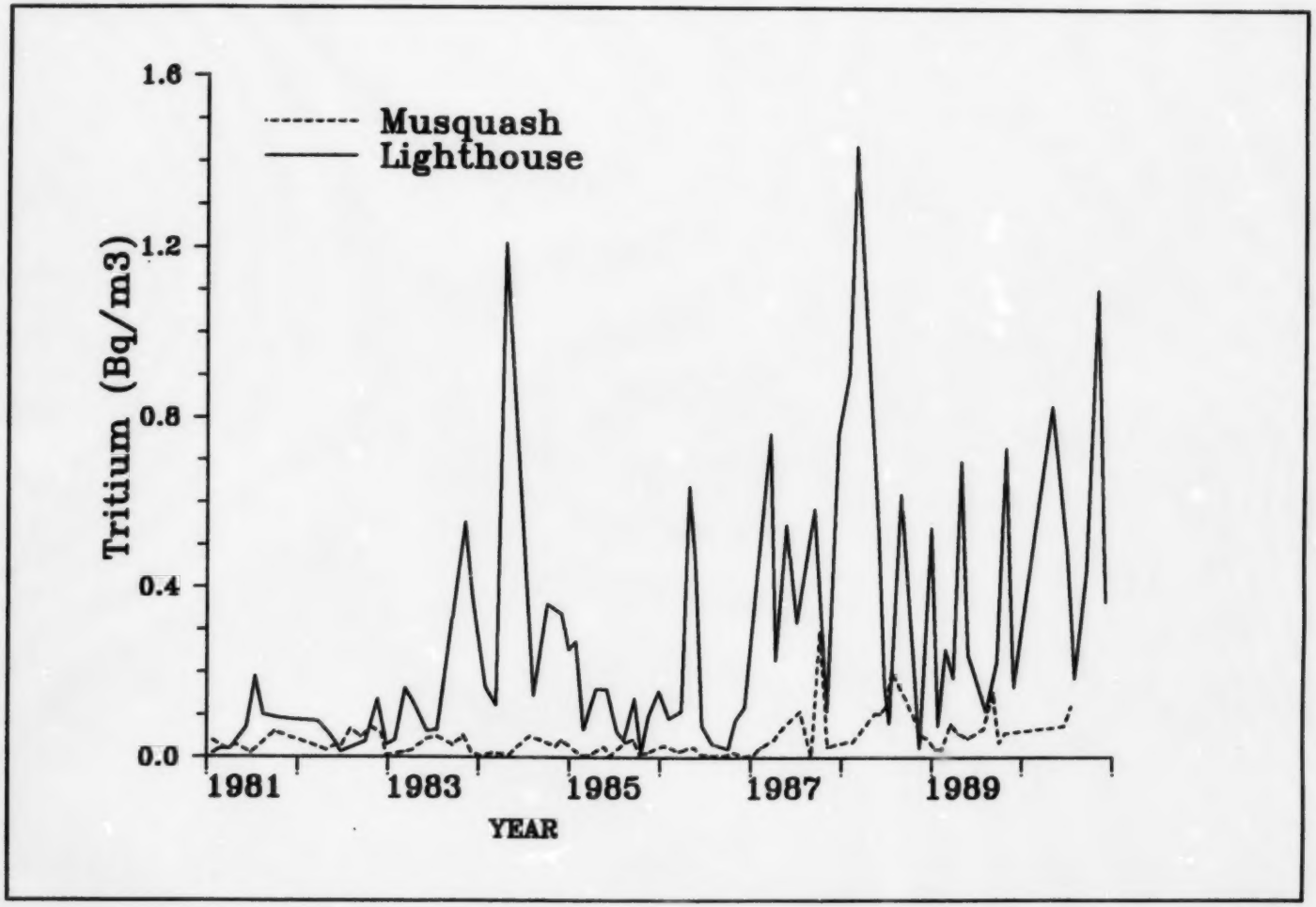

Figure 10: Tritium Activities in Air (Bq/m³) since 1981 at Station 1 (Musquash) and 3 (Point Lepreau).

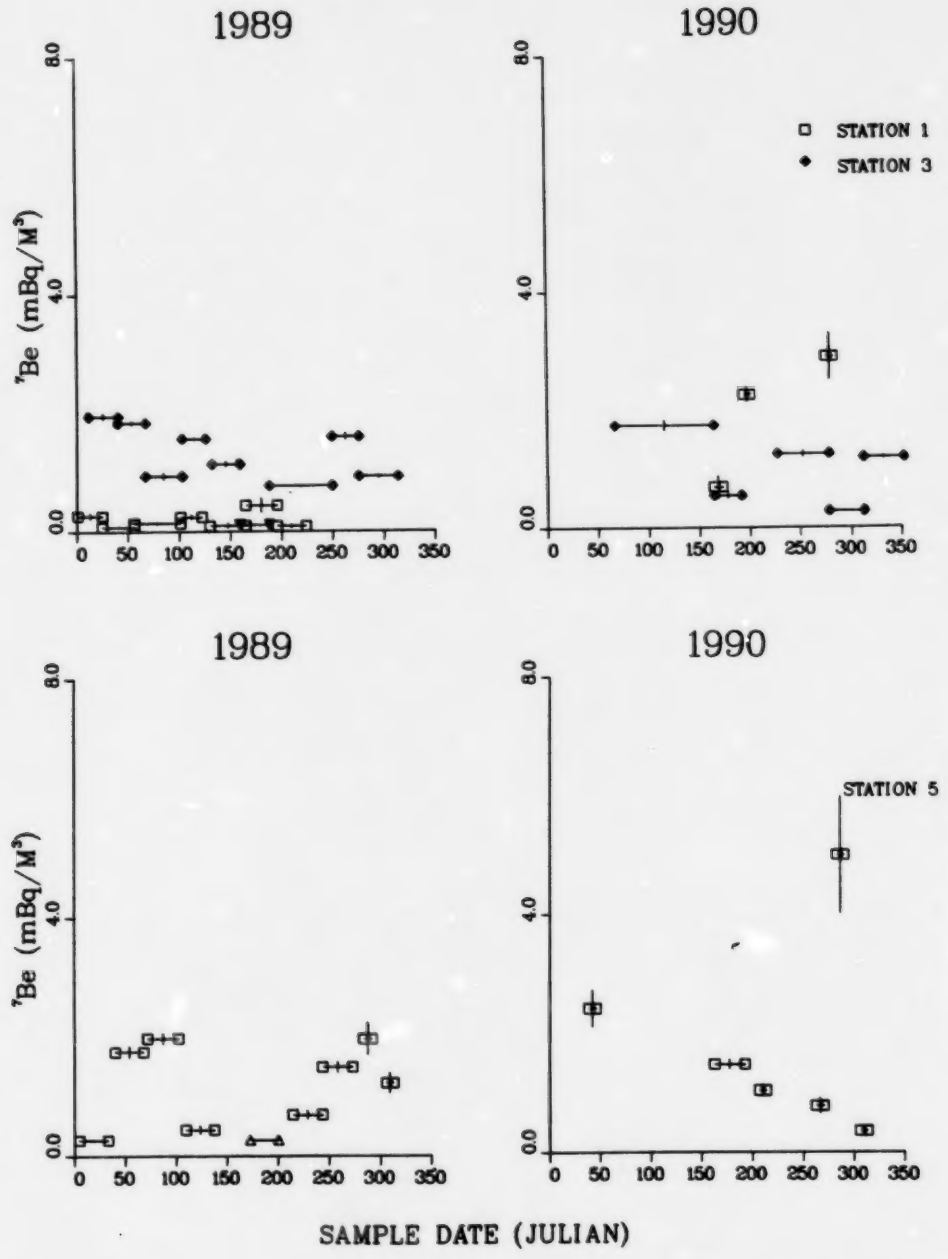

Figure 11: Beryllium-7 Activities Measured in Air Particulates (mBq/m^3) during 1989 and 1990 at Station 1 (Musquash), 3 (Point Lepreau) and 5 (Digby, N.S.).

5.0 MARINE BIOLOGY

The marine biology of the area in the vicinity of the Point Lepreau NGS depends on the gross physical, chemical and biological characteristics of the marine environment including oceanographic variables such as wave action, salinity, water temperature, nutrients, SPM concentrations and sediment type. The bioavailability of radionuclides to the marine biota also depends on factors such as current direction and strength, seasonally-dependant stratification and SPM concentration. Marine organisms can accumulate and redistribute radionuclides which results in an increase in bioconcentration. The accumulation rates and concentrations of radioactivity in marine organisms can be characterized by biological half-lives and concentration factors, respectively. Concentration factors for relevant radionuclides with respect to seawater for various marine groups (IAEA, 1985) are listed in Appendix 4.

5.1 Sampling, Sample Processing and Analysis

Biological sampling sites are indicated in Figure 12. Marine sites are located near the NGS cooling water intake (Indian Cove, I-16) and the outfall (Duck Cove, I-17) in order to assess releases from the Point Lepreau NGS. A site at Digby, N.S. (S-7) is used to assess the movement of radionuclides across the Bay of Fundy. Samples of species considered representative of the area and known to accumulate radionuclides were collected mainly in the intertidal zone.

Samples were freeze-dried, homogenized and analysed directly in one of five different geometries for gamma-emitting radionuclides using a hyperpure-Ge detector with Canberra Spectan-F software. Detection limits for these geometries are given in Appendix 5. The tritium content of biological samples was determined using an azeotrophic distillation method (Moghissi *et al.* 1973).

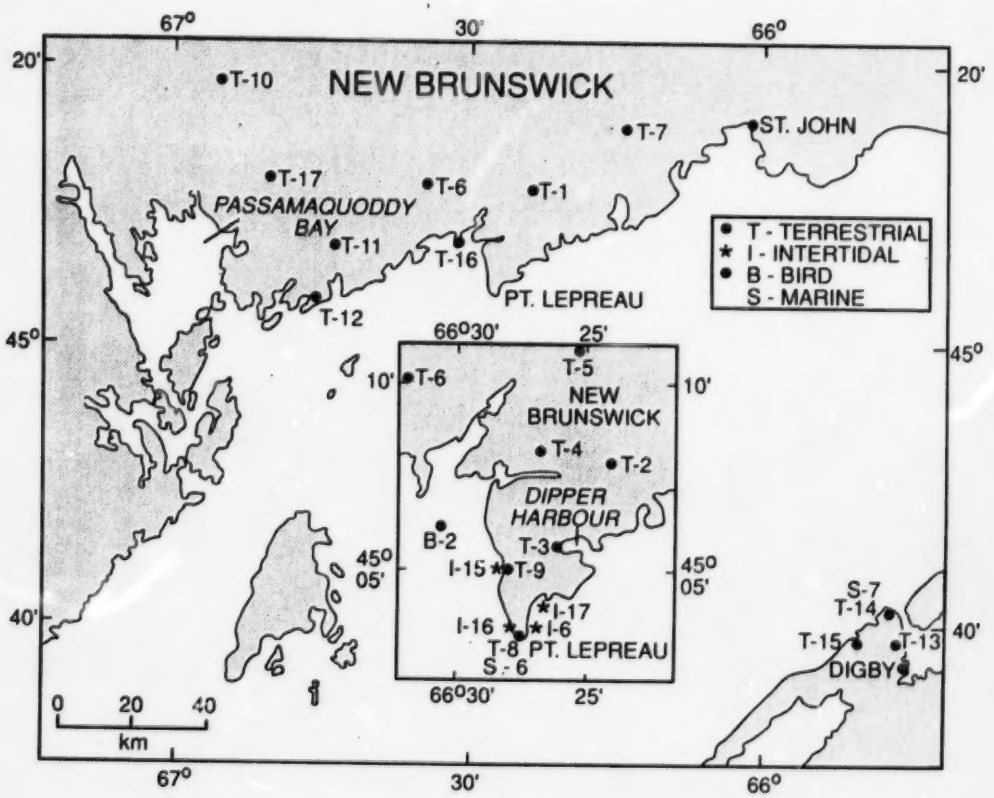

Figure 12: Station Locations for Biological Samples.

5.2 Marine Plants

Species selected for analysis from the intertidal zone include the brown algae *Fucus vesiculosis* and *Ascophyllum nodosom* and dulse (*Rhodymenia sp.*), a red algae. Kelp (*Laminaria sp.*), a brown algae found in the subtidal zone, was also collected. Marine algae, particularily *Fucus* and *Ascophyllum*, are frequently used as bio-indicators for radionuclides in the marine environment (Aarkrog 1985, Carleson and Erlandsson 1991). The results, given in Table 9, are similar to findings from the pre-operational phase. Levels of Cs-137 were below the detection limit with the exception of one *Fucus* sample. Cesium-134, released during the Chernobyl accident in 1986 and measured in one *Fucus* sample in 1988 (Ellis *et al*, 1990), was below the detection limit in all samples.

5.3 Marine Animals

Several species of marine animals were collected from the intertidal zone. Species of marine molluscs analysed included the blue mussel (*Mytilis edulis*) and periwinkle (*Littorina littorea*). *Gammarus oceanicus*, the sea or beach flea, was the only marine crustacean analysed in 1989 and 1990. Cesium-137 activities were below detection limits in all species and no Cs-134 was measured in any samples (Table 9).

5.4 Tritium in Marine Organisms

Samples of algae (*Ascophyllum nodosom, Fucus vesiculosis, Laminaria sp*) and the periwinkle (*Littorina littorea*) were collected from the cooling water intake location at Indian Cove (I-16) and the cooling water release location at Duck Cove (I-17) and analysed for tritium. Tritium activities (Table 10) clearly reflect the different concentrations of this isotope in the water at the intake and the outfall sites. Levels found in biological samples at Duck Cove (67 to 113 Bq/kq) are higher than maximum tritium concentrations in seawater measured at Duck Cove in 1987 (of the order of 29

Table 9: Radionuclide Results for Marine Plants and Animals 1989 and 1990.

Species	Collection Date	Sample No.	Site No.	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)
Seaweed					
Fucus vesiculosis	26/07/89	35763	I-16	< 1	< 1
	26/07/89	35771	I-17	< 1	< 1
	13/06/90	35843	I-16	< 1	< 1
	13/06/90	35852	I-17	5 ± 2	< 1
Ascophyllum nodosom	26/07/89	35764	I-16	< 1	< 1
	26/07/89	35772	I-17	< 1	< 1
	13/06/90	35844	I-16	< 1	< 1
	13/06/90	35851	I-17	< 1	< 1
Laminaria sp.	26/07/89	35765	I-16	< 2	< 2
	13/06/90	35845	I-16	< 2	< 2
Rhodymenia palmata	13/06/90	35846	I-16	< 2	< 2
Marine Animals					
Littorina littorea	26/07/89	35773	I-17	< 1	< 1
	13/06/90	35848	I-16	< 1	< 1
	13/06/90	35853	I-17	< 1	< 1
Gammarus oceanicus	24/07/90	26431	I-17	< 10	< 12
Mytilis edulis	26/07/89	35767	I-16	< 1	< 1

Bq/l, Ellis *et al*, 1990), measured by NBEPC in 1989 or 1990 (Sutherland, 1989, 1990) or levels estimated from release data provided by NBEPC (1990). It is important to note that effluent releases are not continuous and can lead to transient increases in seawater concentrations of tritium of the order of several hundred Bq per litre at the outfall location, depending on the time of discharge. The tritium levels measured in organisms at the outfall location indicate either a bioconcentration of tritium or represent a transient event when the thermal plume drifted directly into Duck Cove with little dilution.

Table 10: Tritium Levels in Marine Plants and Animals in 1990.

Species	Collection Date	Sample No.	Site No.	H-3 (Bq/l)
Ascophyllum nodosom	13/06/90	35844	I-16	6 ± 4
	13/06/90	35851	I-17	113 ± 5
Fucus vesiculosis	13/06/90	35843	I-16	6 ± 4
	13/06/90	35852	I-17	67 ± 7
Littorina littorea	13/06/90	35848	I-16	3 ± 3
	13/06/90	35853	I-17	67 ± 7
Laminaria sp.	13/06/90	35845	I-16	9 ± 3

6.0 FRESHWATER AND TERRESTRIAL PHASES

Radionuclides enter freshwater and terrestrial ecosystems from effluent releases into the atmosphere where they accumulate in soils and lake sediments. Radionuclides from the abiotic phases can enter into organisms phases by ingestion of soils, sediment or air particles, by exposure to the air, absorption from water, inhalation of particles and consumption of food.

The location of the sample sites is given in Figure 12 and includes sites at Digby, N.S. used to assess the transport of radionuclides across the Bay of Fundy. Site T-3b is located 100 m upstream from site T-3. Samples are processed and analysed as described in the Section 5.1.

6.1 Freshwater Systems

Distributions of radionuclides in the aquatic environment are governed by factors such as light intensity, temperature, redox condition, particle uptake and sedimentation processes and differ from distributions in the marine environment mainly as a result of differences in ionic strengths of the two mediums.

The location of the seven sampling sites (T-1 to T-5, T-8 and T-9) is given in Figure 12. Site T-3b is located 100 m upstream from site T-3. Two of the sites are small lakes (T-2 and T-4) and the others are stream locations.

6.1.1 Water Column Results

Freshwater samples were collected during field trips in 1989 and 1990. The results are presented in Table 11. Cesium-137 levels are below the detection limit in both dissolved and particulate phases. Tritium activities are highest near the reactor (T-3, T-3b, T-8 and T-9). In the months preceeding the sampling periods of June and July, the wind field was dominated by northeast

Table 11: Tritium and Cs-137 Activities in Fresh Water Samples in 1989 and 1990.

Collection Date	Sample No.	Site No.	Cs-137 Activity (mBq/l)	Tritium Activity (Bq/l)
26/07/89	35753	T-6	-	< 2
26/07/89	35762	T-8	-	25 ± 3
26/07/89	35768	T-3b	-	162 ± 5
26/07/89	35775	T-4	-	7 ± 3
26/07/89	35780	T-9	-	29 ± 3
26/07/89	35787	T-3	-	17 ± 3
26/07/89	35789	T-1	-	7 ± 3
26/07/89	35769	T-3b	soluble < 1 part. < 2	-
13/06/90	35828	T-1	-	6 ± 3
13/06/90	35833	T-3	-	22 ± 3
13/16/90	35841	T-8	-	53 ± 4
13/06/90	35860	T-9	-	29 ± 3
13/06/90	35864	T-4	-	5 ± 3
13/06/90	35869	T-6	-	4 ± 3
13/06/90	35874	T-5	-	5 ± 3
13/06/90	35854	T-3b	soluble < 1 part. < 2	-

and southwest winds, distributing the atmospheric effluent from the reactor between T-3 and T-3b at Dipper Harbour and T-8 and T-9 at the tip of Point Lepreau. Tritium activities measured in freshwater at T-8 and T-9 are similar to air sample activities (Bq/l) measured simultaneously (Station 3, Figure 7).

6.1.3 Freshwater Plants and Animals

Freshwater plants collected and analysed in 1989 and 1990 (Table 12) include horsetail (*Equisetum sp.*), a common plant found along streams and in lakes in the Point Lepreau area and

Table 12: Radionuclide Results for Aquatic Plants for 1989 and 1990.

Species	Collection Date	Sample No.	Site No.	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)
Iris (*Iris versicolor*)	26/07/89	35756	T-6	16 ± 1	< 2
	26/07/89	35776	T-4	< 2	< 2
	13/06/90	35842	T-8	5 ± 2	< 2
Horsetail (*Equisetum sp.*)	24/07/89	35747	T-15	< 4	< 5
	24/07/89	35752	T-13	6.8 ± 0.5	< 1
	26/07/89	35757	T-6	6 ± 1	< 1
	26/07/89	35761	T-8	8 ± 1	< 2
	26/07/89	35777	T-4	< 1	< 2
	26/07/89	35782	T-9	6 ± 1	< 2
	26/07/89	35785	T-3	11 ± 1	< 1
	26/07/89	35792	T-1	< 2	< 3
	26/07/89	35794	T-5	7 ± 2	< 5
	13/06/90	35831	T-1	2 ± 1	< 2
	13/06/90	35835	T-3	7 ± 2	< 2
	13/06/90	35859	T-3b	5 ± 2	< 3
	13/06/90	35867	T-4	1 ± 1	< 2
	13/06/90	35877	T-5	9 ± 3	< 2
	13/06/90	35872	T-6	1 ± 1	< 2
	13/06/90	35840	T-8	4 ± 1	< 2
	13/06/90	35863	T-9	3 ± 2	< 2
	13/06/90	35827	T-13	8 ± 2	< 2
	13/06/90	35822	T-15	< 2	< 3

wild iris (*Iris veriscolor*). Cesium-137 was measured near the detection limit in these samples, having an average value of 5 Bq/kg, within the range of pre-operational levels.

Animal species sampled include frog (*Rana sp.*) and freshwater fish (*Cyprinidae sp.* and *Gasterosteidae sp.*). Cesium-137 levels in these samples (Table 13) were at the levels measured during the pre-operational stage.

Table 13: Radionuclide Results for Aquatic Animals for 1990.

Species	No. of Animals	Collection Date	Sample No.	Site No.	Cs-137 (Bq/kg)
Fish (*Cyprinidae sp.* and *Gasterosteidae sp.*)	2	30/07/90	33343	T-1	20 ± 1
	3	30/07/90	33341	T-4	8 ± 1
	4	30/07/90	33342	T-4	5 ± 1
	4	30/07/90	33349	T-1	13 ± 1
Frog (*Rana sp.*)	2	30/07/90	33351	T-4	3 ± 2
	3	30/07/90	33352	T-1	9 ± 2

6.2 TERRESTRIAL SYSTEMS

Biological uptake of fallout radioactivity is generally more efficient in the terrestrial environment compared to the freshwater and marine systems due to the absence of water as a diluting medium, resulting in higher concentrations of fallout radionuclides as illustrated in previous PLEMP studies (Ellis *et al*, 1984, Nelson *et al*, 1985, 1986, 1988).

6.2.1 Terrestrial Plants

The plant species selected for analysis include blueberry leaves (*Vaccinium sp*), alder (*Alnus rugosa*), spruce needles and two types of lichen - *Cladonia sp.*, a ground lichen and *Usnea sp.*, an arboreal lichen commonly known as "old man's" beard or spanish moss.

Blueberry and Alder

Results for gamma-emitting radionuclides in blueberry and alder leaves for 1989 and 1990 are given in Table 14. Cesium-137 and Be-7 were detected in most samples, over a wide range of values. The average Cs-137 concentration (16.8 Bq/kg in blueberry leaves and 13.6 Bq/kg in alder in 1989 and 5.0 Bq/kg for both species in 1990) shows a decreasing trend with time as a result of the radioactive decay of previously accumulated Cs-137 and reduced inputs from atmospheric nuclear testing. One exception occurred in the summer of 1986, when the Chernobyl nuclear accident in the USSR led to additional atmospheric Cs-137 deposition in eastern Canada and slightly increased levels were measured (Nelson *et al*, 1988).

Lichen

Lichen communities have long been recognized as a concentrators of natural and artificial radionuclides. The accumulation of radionuclides is enhanced by the plant's persistant aerial parts, slow growth rate, long life span, high surface to mass ratio and its foliar absorption of nutrients. Modelling of radionuclide uptake by lichen at Point Lepreau (Ellis and Smith, 1987) has shown that ground lichen retains 10 to 30 % of the fallout deposition.

The radionuclide results for the ground and aerial lichen collected at three sites throughout 1989 and 1990 are given in Table 15. A similar range of Cs-137 values was measured at the same time for ground lichen samples analysed by NBEPC (10-67 Bq/kg, Sutherland, 1989, 1990). Levels of Cs-137 have tended to decrease with time since 1980, as shown in Figure 13 for *Cladonia* and Figure 14 for *Usnea*. The Point Lepreau NGS has not contributed any measureable Cs-137 to lichen and, in fact, the Cs-137 activities in lichen have coincidently decreased since the reactor startup as a result of radioactive decay and the decrease of atmospheric nuclear fallout. The higher activities of Cs-137 in *Cladonia* are due to the longer biological half-life of cesium in *Cladonia* (Ellis and

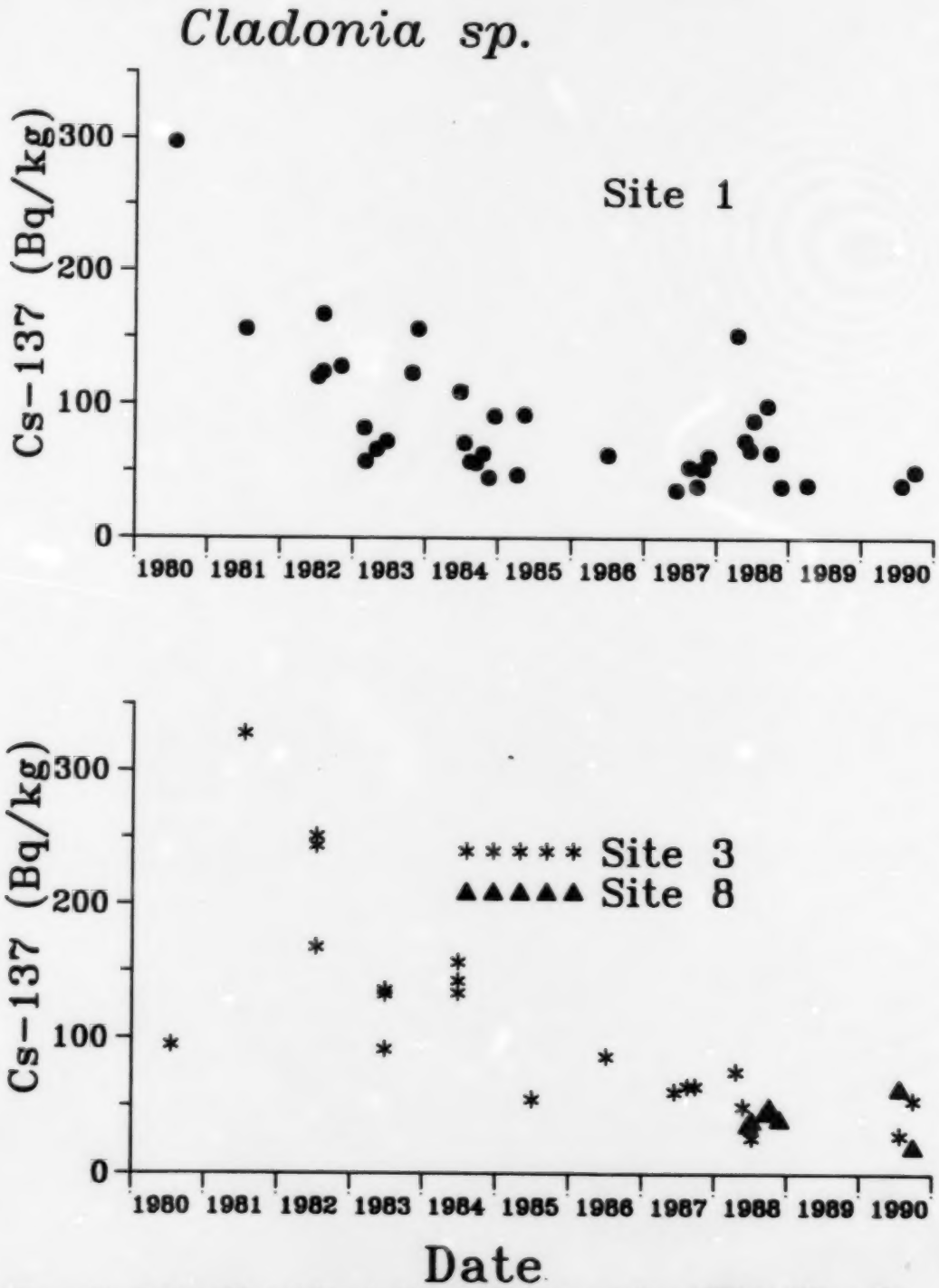

Figure 13: Cesium-137 Activities in Lichen (*Cladonia sp.*) from 1980 to 1991 at T-1 (Musquash), T-3 (Dipper Harbour) and T-8 (Point Lepreau).

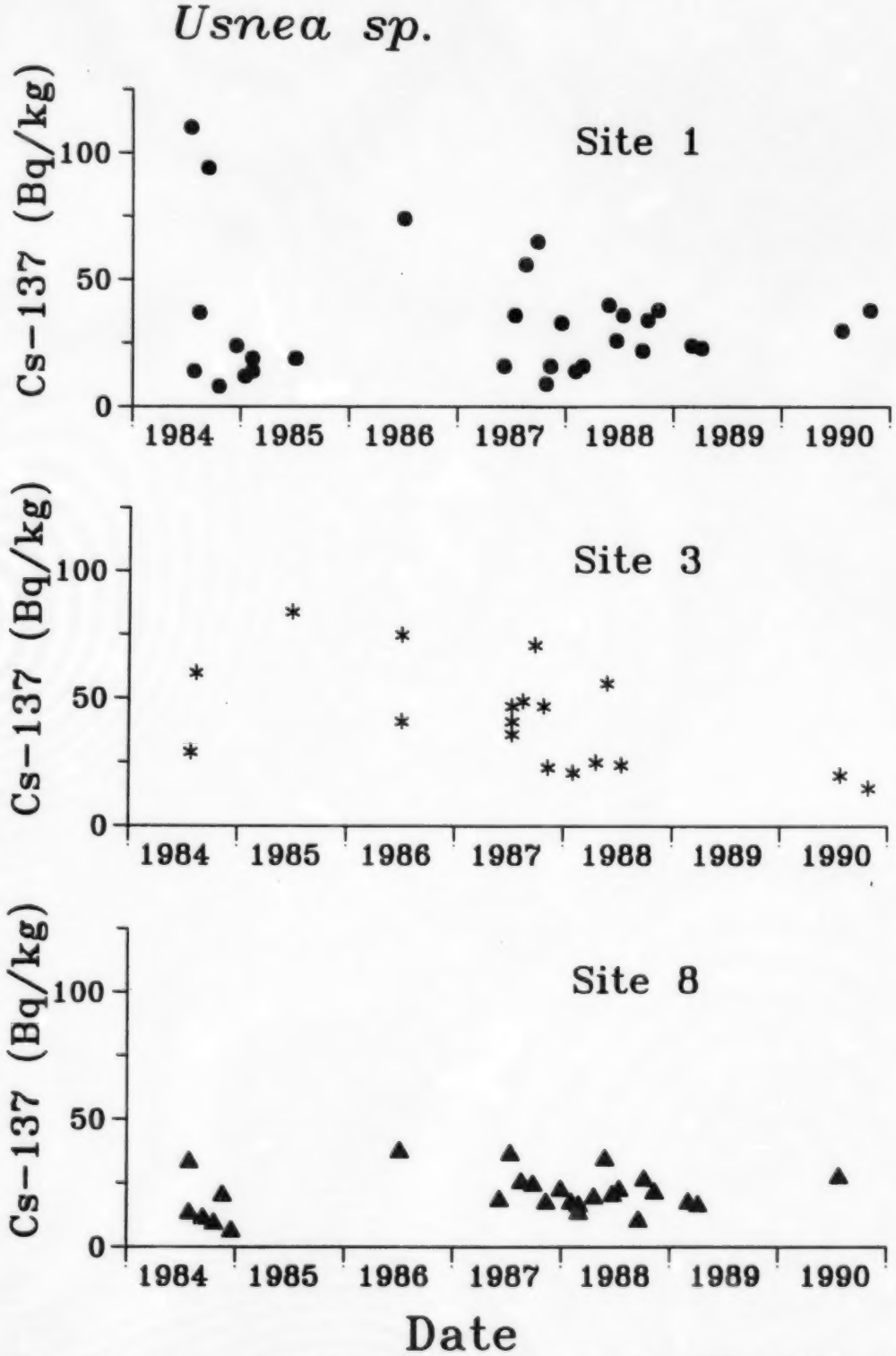

Figure 14: Cesium-137 Activities in Lichen (*Usnea sp.*) from 1980 to 1991 at T-1 (Musquash), T-3 (Dipper Harbour) and T-8 (Point Lepreau).

Table 14: Radionuclide Results for Terrestrial Plants for 1989 and 1990.

Species	Collection Date	Sample No.	Site No.	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)	Be-7 (Bq/kg)
Blueberry (*Vaccinium sp.*)	24/07/89	35745	T-15	9 ± 1	< 3	176 ± 52
	24/07/89	35758	T-6	5 ± 1	< 2	< 202
	24/07/89	35788	T-3	52 ± 2	< 3	491 ± 112
	24/07/89	35793	T-1	1.0 ± 0.3	< 1	41 ± 12
	13/06/90	35830	T-1	5 ± 1	< 2	90 ± 46
	13/06/90	35868	T-4	12 ± 2	< 2	147 ± 101
	13/06/90	35873	T-6	4 ± 1	< 2	< 100
	13/06/90	35838	T-8	< 1	< 2	80 ± 5
Alder (*Alnus rugosa*)	24/07/89	35744	T-15	2 ± 1	< 1	< 90
	24/07/89	35749	T-14	2 ± 1	< 2	< 111
	24/07/89	35751	T-13	38 ± 1	< 1	< 84
	26/07/89	35754	T-6	13 ± 1	< 2	< 129
	26/07/90	35759	T-8	19 ± 1	< 2	< 107
	26/07/89	35779	T-4	< 1	< 2	139 ± 39
	26/07/89	35781	T-9	4 ± 1	< 2	< 130
	26/07/89	35784	T-3	5 ± 1	< 1	< 79
	26/07/89	35791	T-1	47 ± 1	< 2	< 115
	26/07/89	35795	T-5	5 ± 1	< 1	161 ± 40
	13/06/90	35836	T-3	2 ± 1	< 2	-
	13/06/90	35857	T-3B	11 ± 1	< 2	-
	13/06/90	35866	T-4	7 ± 1	< 2	-
	13/06/90	35870	T-6	2 ± 1	< 2	< 100
	13/06/90	35839	T-8	8 ± 1	< 2	-
	11/06/90	35826	T-13	3.1±0.4	< 1	-
	11/06/90	35823	T-15	2 ± 1	< 2	-

Table 15: Radionuclide Results for Lichen collected in 1989 and 1990.

Species	Collection Date	Sample No.	Site No.	Cs-137 Bq/kg	Cs-134 Bq/kg	Be-7 Bq/kg
Cladonia sp.	04/04/89	35999	T-1	40 ± 4	< 4	466 ± 38
	23/07/90	26432	T-3	29 ± 1	< 2	302 ± 20
	24/07/90	26462	T-1	40 ± 5	< 10	< 377
	24/07/89	26433	T-8	64 ± 2	< 3	322 ± 61
	26/09/90	33350	T-8	21 ± 3	< 2	1592 ± 462
	26/09/90	33346	T-3	55 ± 4	< 6	430 ± 61
	26/09/89	33348	T-1	50 ± 4	< 5	457 ± 47
Usnea sp.	03/03/89	33440	T-8	18 ± 4	< 6	156 ± 49
	03/03/89	33442	T-1	24 ± 6	< 1	< 86
	04/04/89	35997	T-8	17 ± 5	< 1	177 ± 51
	04/04/89	35998	T-1	23 ± 6	< 1	114 ± 67
	23/07/90	26464	T-3	20 ± 3	< 7	< 238
	24/07/90	26434	T-1	30 ± 3	< 6	< 226
	24/07/90	26465	T-8	28 ± 3	< 7	< 251
	26/09/90	33345	T-3	15 ± 4	< 9	< 160
	26/09/90	33347	T-1	38 ± 5	< 3	270 ±114

Smith, 1987, Martin and Koranda, 1971). Activities are similar at each site and small differences have been previously shown to be consistent with the Be-7 activities. The relationship between Be-7, a naturally occurring radionuclide, and fallout Cs-137 permit the estimate of the lichen collection efficiency for atmospheric fallout radionuclides (Ellis and Smith, 1987, Nelson *et al*, 1988). Unfortunately, delays between sampling and counting times have led to high detection limits for short-lived Be-7 in many cases, making comparison of Cs-137 to Be-7 difficult. Generally, a good correlation between Be-7 and Cs-137 was found for *Usnea* and a poor correlation found for *Cladonia*.

Arboreal lichens such as *Usnea* obtain their nutrients directly from the atmosphere resulting in similar isotopic ratios in lichen and the atmosphere. The accumulation of radionuclides in ground lichen occurs via several pathways such as soil and rain, leading to fractionation and delays in uptake owing to different of different isotope half-lives and residence times in preceeding environmental reservoirs.

6.3 Tritium in Freshwater and Terrestrial Systems

The majority of tritium enters the environment from the reactor in the form of tritiated water (HTO). Absorption of HTO by plants occurs through exchange between atmospheric moisture and foliar water (Belot, 1986). Uptake also occurs through the root or rhyzoid system by the same process and at rates similar to the uptake of natural water (Murphy *et al*, 1982).

Tritium activities measured in conifer needles from three locations, collected at various intervals during the year, are given in Table 16 for 1989 and Table 17 for 1990. As noted in previous reports, the wide range of tritium activities measured (< 3 to 526 Bq/l for 1989 and < 0.1 to 396 Bq/l for 1990) reflects the variability in atmospheric tritium levels. A temporal comparison of the tritium activities in conifer needles to those in atmopheric moisture at the same locations is illustrated in Figure 15 for 1989 and 1990. Levels measured in conifer needles are remarkedly similar to levels measured in atmospheric moisture during the same time period at each location. Levels are highest at T-8, closest to the reactor, next highest at T-3, Dipper Harbour, located 2.5 km northeast of the reactor and lowest at T-1, 17 km northeast of the reactor. Tritium levels at T-8 and Station 3 show peaks during the winter of 1989/90 as a result of the prevailing northwest winds (Figure 5). It is interesting to compare these tritium levels with those from the winter of 1987/88 (Ellis *et al*, 1990) when the winter prevailing winds were southwest and northwest and an enhanced tritium release was observed. Under these conditions, T-3 was downwind of the reactor and tritium

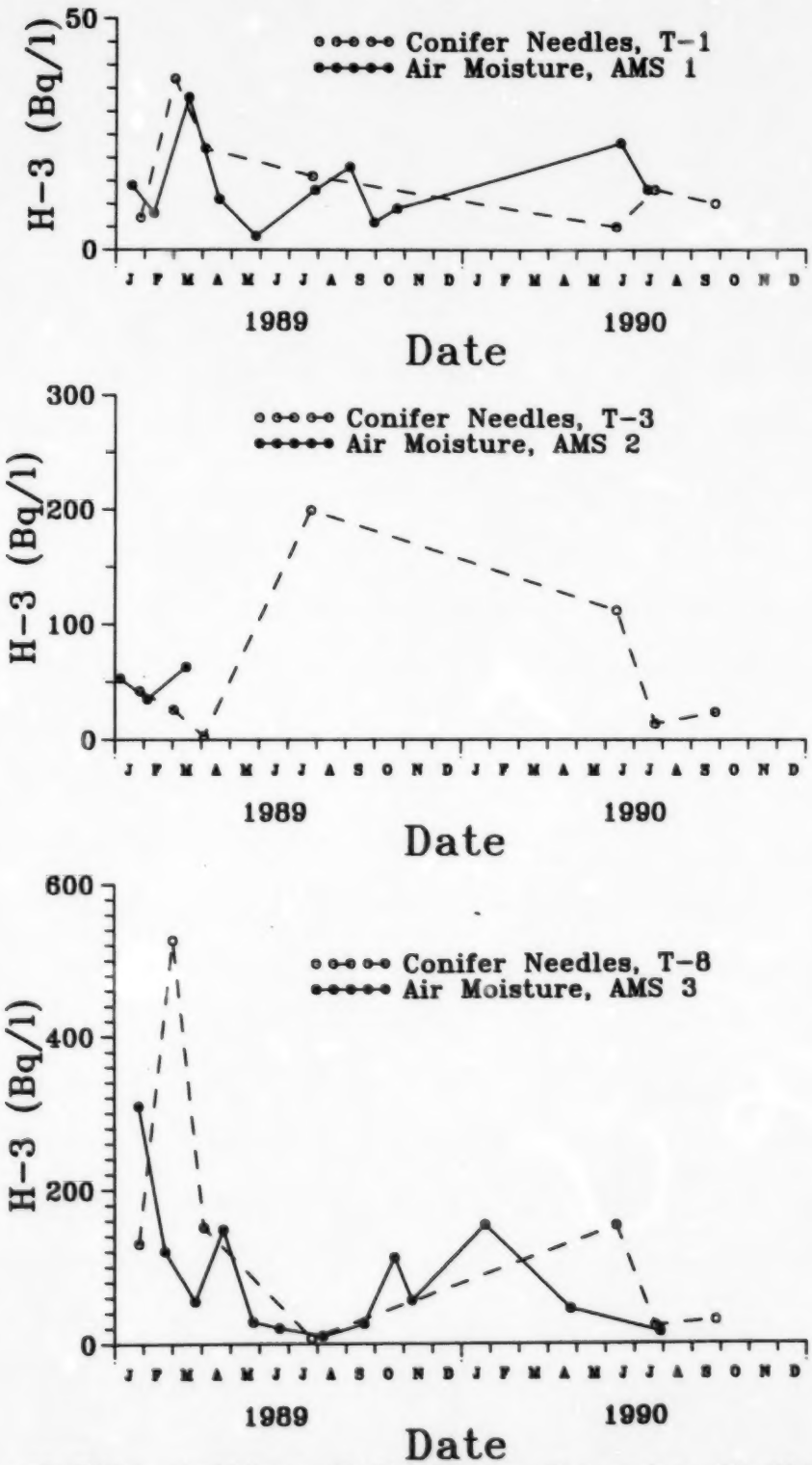

Figure 15: Tritium Activities in Conifer Needles Compared to Air Moisture at Terrestrial Sample Sites T-1 (Musquash), T-3 (Dipper Harbour) and T-8 (Point Lepreau) for 1989 and 1990.

Table 16: Tritium Results for Conifer Needles Collected in 1989.

Collection Date	Sample No.	Site No.	H-3 (Bq/l)
26/01/89	33435	T-8	130 ± 4
26/01/89	33436	T-3	42 ± 3
26/01/89	33438	T-1	7 ± 3
26/01/89	33439	T-9	92 ± 4
03/03/89	33440	T-8	526 ± 11
03/03/89	33441	T-3	26 ± 3
03/03/89	33442	T-1	37 ± 3
03/03/89	33443	T-9	33 ± 3
03/03/89	33444	T-9	29
03/03/89	33445	T-3	< 3
03/03/89	33446	T-1	22 ± 3
03/03/89	33447	T-8	151
24/07/89	35746	T-15	2 ± 2
24/07/89	35748	T-14	5 ± 3
24/07/89	35750	T-13	< 4
26/07/89	35755	T-6	3 ± 3
26/07/89	35760	T-8	7 ± 3
26/07/89	35778	T-4	3 ± 3
26/07/89	35783	T-9	11 ± 3
26/07/89	35786	T-3	199 ± 3
26/07/89	35790	T-1	16 ± 3
26/07/89	35796	T-5	4 ± 3

Table 17: Tritium Results for Conifer Needles Collected in 1990.

Collection Date	Sample No.	Site No.	H-3 (Bq/l)
24/07/90	33353	T-1	13 ± 3
24/07/90	33354	T-8	23 ± 3
24/07/90	33355	T-3	14 ± 3
26/09/90	33356	T-1	10 ± 3
26/09/90	33357	T-8	30 ± 3
26/09/90	33358	T-3	24 ± 3
13/06/90	35824	T-15	5 ± 3
13/06/90	35825	T-13	7 ± 3
13/06/90	35832	T-1	6 ± 3
13/06/90	35834	T-3	117 ± 4
13/06/90	35837	T-8	159 ± 4
13/06/90	35858	T-3b	396 ± 8
13/06/90	35861	T-9	12 ± 3
13/06/90	35865	T-4	17 ± 3
13/06/90	35871	T-6	5 ± 3
13/06/90	35876	T-5	LC = 0.1

levels were as high as those at T-8. In the winter of 1989/90, much lower levels were observed at T-3, as a result of a weaker southwest wind vector. Levels of tritium at T-3 during 1989 and 1990 peaked in the summer, when the southwesterly wind strength was maximal (Figure 6).

Tritium levels measured in terrestrial samples in the Digby area (Sites T-13 to T-15) were in the range of those measured in atmospheric water vapour during this time period (Station 5, Figure 7) and were in agreement with pre-operational levels, showing no discernable effect from the Point Lepreau NGS.

7.0 LABORATORY INTERCOMPARISON PROGRAM

The AERU laboratory participates in an ongoing laboratory intercomparison program run by the United States Environmental Protection Agency (EPA) in order to maintain a check on the laboratory's performance for accuracy and precision of radionuclide results. The results of the 'blind' intercomparison are published and distributed to all participants (Laboratory Number for AERU is 1-A). The EPA provides a wide range of sample materials to ensure a routine check on all sample types.

The intercomparison results for 1989 and 1990 are presented in Table 18. Cesium-137 measurements on air filters continue to be in excellent agreement with EPA values as are the values for tritium and I-131. The agreement of the AERU and EPA Cs-137 and Cs-134 values in water samples is generally good, although some scatter is observed. Cobalt-60, Zn-65, Ru-106 and Ba-133 values for water are generally in good agreement with EPA values. The single analysis of Ra-226 in water revealed low values for the AERU laboratory. More samples will be analysed to investigate these low values.

An intercalibration of 'Radionuclide in Sediment' samples provided by the International Atomic Energy Agency (IAEA) was carried out during 1989 and 1990 and the results are presented in Table 19 (Ballestra *et al*, 1991a, 1991b). The agreement is very good for Cs-137, Pu-239,240 and Pb-210 in sediments. A calibration error for K-40 has been identified by AERU and is presently being investigated.

Table 18: Results for intercalibration samples from EPA. Units for air filters are pCi and for water pCi/l.

Type	Collect Date	Nuclide	EPA Value	AERU Value	AERU SD	All Labs SD	AERU/ EPA
Air Filter	31/03/89	Cs-137	20	20	2	5	1.00
	25/08/89	Cs-137	10	10	0	5	1.00
	30/03/90	Cs-137	10	12	1	2	1.20
Water	22/06/90	H-3	2933	2826	69	285	0.96
	19/10/90	H-3	7203	7078	101	671	0.98
Water	17/02/89	I-131	106	118	2	11	1.11
	04/08/89	I-131	83	79	4	8	0.95
Water	17/04/90	Ra-226	5.0	3.6	0.1	0.8	0.73
Water	18/04/89	Cs-134	20	13	3	5	0.65
		Cs-137	20	22	2	5	1.10
	09/06/89	Ba-133	49	47	8	5	0.96
		Zn-65	165	118	21	17	0.72
		Ru-106	128	100	12	13	0.78
		Cs-134	39	40	7	5	1.03
		Cs-137	20	19	2	5	0.95
	05/10/90	Co-60	20	26	1	3	1.30
		Zn-65	115	146	7	10	1.27
		Ru-106	151	165	13	15	1.09
		Cs-134	12	11	2	2	0.92
		Cs-137	12	17	1	2	1.42
		Ba-133	110	130	3	9	1.18

Table 19: Results for Intercalibration 'Radionuclides in Sediment' Samples provided by the International Atomic Energy Agency.

Sample No.	Nuclide	IAEA Value (Bq/kg)	AERU Value (Bq/kg)	AERU SD (Bq/kg)	AERU/ IAEA
IAEA-367	Cs-137	199*	187	7	0.94
	Pu-239,240	39*	33	3	0.85
IAEA-368	Cs-137	0.34**	< 0.5	-	-
	K-40	39**	246	37	-
	Pb-210	24**	26	2	1.08
	Pu-239,240	32**	30	2	0.94

* Ballestra et al, 1991a
** Ballestra et al, 1991b

8.0 CONCLUSIONS

1. A cost-effective reduction in the sampling program was achieved in 1989 and 1990 by restricting the sampling sites to three ground locations at Point Lepreau, N.B. and Digby, N.S, and to two intertidal locations at the cooling water intake and outlet. The number of air monitoring stations was reduced from five to three and samples of indicator species, identified in previous years, were collected from these sites.

2. Tritium remains the only radionuclide released from the Point Lepreau NGS which can be detected in vegetation, water and air. Levels are significantly below those considered to be harmful to organisms.

3. Tritium activities in air have increased over those of previous years as is expected over the lifetime of the nuclear reactor. Maximum values of 1.10 Bq/m^3 in air and 300 Bq/l in atmospheric water vapour were measured at the tip of Point Lepreau. Tritium levels at Musquash have been found to exceed pre-operational levels occasionally and this station can no longer be considered as a control station; the Digby station now fulfills this role.

3. Levels of tritium measured in marine organisms in 1990 in the vicinity of the effluent discharge from the Point Lepreau NGS are higher than baseline levels and reflect releases from the reactor. Elevated levels are rarely measured at distances greater than a few kilometres from the point of discharge.

4. Levels of Cs-137 measured in terrestrial and freshwater plants have decreased as a result of the radioactive decay of previously deposited material and decreased inputs from atmospheric nuclear testing. No environmental increases of Cs-137 have been observed as a result of releases from the Point Lepreau NGS.

5. Tritium levels in terrestrial plants accurately reflect the activities measured in the air because of their rapid uptake of atmospheric water vapour. Elevated levels of tritium measured on the Point Lepreau peninsula in plants and air in 1989 and 1990 are due to the proximity of this station to the reactor and its downwind location. The highest tritium levels were measured in samples collected at Site T-8 at the tip of the Point Lepreau peninsula.

6. Tritium levels in air, terrestrial plants and marine samples at Digby, N.S. remain at levels measured during the pre-operational program and there is no evidence of contamination from the Point Lepreau NGS.

7. In contrast to the results of 1987 and 1988, no traces of Cs-134 from the Chernobyl accident in May 1986 were found in any samples in 1989 or 1990.

ACKNOWLEDGEMENTS

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Residents of Point Lepreau, N.B., provided great assistance in the operation of the air monitoring stations including Mr and Mrs. G. Thompson (Dipper Harbour), Mr. R. Mawhinney (Welch's Cove) and the staff at the New Brunswick Department of Transport depot at Musquash, particularily E. Thompson. Mr. M. Durkee provided similar support at Digby, N.S. Appreciation is also extended to members of the N.B. Electric Power Commission's Health Physics Department who helped with the deployment, maintenance and operation of air monitoring equipment and provided information regarding reactor operation, namely Dr. J. Paciga, J. McCulley, J. O'Donnell and C. Nason.

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APPENDIX 2: PLEMP REPORTS

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APPENDIX 3: Conversion Factors for Radionuclide Units

1 Becquerel (Bq)	=	60 dpm
	=	27 pCi
	=	2.7×10^{-11} Curies (Ci)
1 Bq/l	=	8.3 tritium units (TU)
1 Ci	=	3.7×10^{10} Bq
1 mCi	=	3.7×10^{7} Bq
1 pCi	=	3.7×10^{-2} Bq
1 dpm	=	0.0167 Bq
1 dpm	=	0.45 pCi
1 Tu	=	0.12 Bq/l
1 Tu	=	7.2 dpm/l
1 mCi/km^2	=	37 Bq/m^2

APPENDIX 4: Concentration Factors for Radionuclides from Seawater for Various Marine Groups (IAEA,1985).

Radio-nuclide	Half-Life	Plankton	Macro-Algae	Crusta-cean	Mollusc	Pelagic Fish
Ce-141	33.0 d	$9x10^4$	$5x10^3$	$1x10^3$	$5x10^3$	$5x10^1$
Ce-144	284.4 d	$9x10^4$	$5x10^3$	$1x10^3$	$5x10^3$	$5x10^1$
Co-58	71.2 d	$5x10^3$	$1x10^4$	$5x10^3$	$5x10^3$	$1x10^3$
Co-60	5.3 y	$5x10^3$	$1x10^4$	$5x10^3$	$5x10^3$	$1x10^3$
Cr-51	27.7 d	$2x10^3$	$2x10^3$	$5x10^2$	$8x10^2$	$2x10^2$
Cs-134	5.2 y	$2x10^1$	$5x10^1$	$3x10^1$	$3x10^1$	$1x10^2$
Cs-137	30.2 y	$2x10^1$	$5x10^1$	$3x10^1$	$3x10^1$	$1x10^2$
Fe-55	2.6 y	$6x10^4$	$3x10^4$	$5x10^3$	$3x10^4$	$3x10^3$
I-131	8.1 d	$1x10^3$	$1x10^3$	$1x10^1$	$1x10^1$	$1x10^1$
Mn-54	321.6 d	$6x10^3$	$6x10^3$	$5x10^2$	$5x10^3$	$4x10^2$
Nb-95	35.2 d	$1x10^3$	$3x10^3$	$2x10^2$	$1x10^3$	$3x10^1$
Ru-103	39.4 d	$2x10^5$	$2x10^3$	$1x10^2$	$2x10^3$	$2x10^0$
Ru-106	368.0 d	$2x10^5$	$2x10^3$	$1x10^2$	$2x10^3$	$2x10^0$
Zn-65	244.1 d	$3x10^4$	$2x10^4$	$5x10^4$	$3x10^4$	$1x10^3$
Zr-95	65.0 d	$6x10^4$	$3x10^3$	$2x10^2$	$5x10^3$	$2x10^1$

APPENDIX 5:

Detection limits (Bq) for gamma-emitting radionuclides and geometry under normal counting conditions of 1 day counting time, performed one month after sample collection. The detection limit (Bq/kg) for each radionuclide for a specific sample is determined by dividing the detection limit, found from the table for the correct geometry, by the sample weight.

Nuclide	Half- Life	Geom 1	Geom 2	Geom 3	Geom 4	Geom 5
Ag-110m	253 d	0.046	0.040	0.032	0.021	0.064
Ba-140	12.8 d	0.873	0.755	0.588	0.390	0.299
Be-7	53.6 d	0.507	0.431	0.335	0.221	0.169
Ce-141	32.4 d	0.089	0.064	0.048	0.030	0.023
Ce-144	284 d	0.235	0.161	0.119	0.074	0.057
Co-56	77 d	0.061	0.054	0.044	0.029	0.023
Co-57	270 d	0.029	0.019	0.014	0.009	0.007
Co-58	71 d	0.060	0.053	0.043	0.029	0.022
Co-60	5.26 y	0.057	0.051	0.041	0.030	0.022
Cr-51	28 d	0.718	0.592	0.445	0.296	0.222
Cs-134	2.07 y	0.043	0.037	0.029	0.019	0.015
Cs-137	30.2 y	0.046	0.041	0.032	0.021	0.017
Fe-59	44.6 d	0.148	0.133	0.108	0.076	0.058
I-131	8.06 d	0.621	0.517	0.393	0.261	0.197
La-140	40.2 h	32800	29990	23900	18600	13200
Mn-54	313 d	0.050	0.044	0.035	0.024	0.018
Nb-95	35.1 d	0.080	0.071	0.057	0.038	0.030
Ru-103	39.6 d	0.070	0.060	0.047	0.031	0.024
Ru-106	365 d	0.409	0.355	0.282	0.186	0.144
Sb-124	60.2 d	0.059	0.051	0.041	0.027	0.021
Sb-125	2.7 y	0.094	0.094	0.072	0.048	0.036
Zn-65	244 d	0.226	0.226	0.183	0.129	0.098
Zr-95	64 d	0.091	0.091	0.073	0.049	0.038